

Lithologic Descriptions of Piston Cores from Chesapeake Bay, Maryland

by

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INTRODUCTION

The U.S Geological Survey is conducting research investigations to understand the nutrient and sediment history of Chesapeake Bay over various time scales and to determine the impact of nutrients and sediment history on living resources. To do this, U.S. Geological Survey will process and analyze various ecological indicators obtained by the sediments.

The Maryland Geological Survey, Resources Assessment Service of the Maryland Department of Natural Resources enter into a cooperative agreement to assist the U.S. Geological Survey in their Critical Ecosystem Program. This cooperative agreement provides support to the Maryland Geological Survey to conduct sediment coring and lithologic core description in Chesapeake Bay in conjunction with U.S. Geological Survey Critical Ecosystem Program to further the understanding of Chesapeake Bay ecosystems.

The objective of this proposal is to obtain continuous sequences of sediments from the Holocene interval of the Chesapeake Bay which consists of the stratigraphic units that fill the Cape Charles paleochannel in the Maryland portion of the Bay.

PRESENT DAY MORPHOLOGY

The Chesapeake Bay, the largest estuary in the United States, is a classic coastal plain estuary located on a trailing edge continental margin. It is nearly 300 km long and ranges from 8 to 48 km wide, having a surface area of almost 6000 square km. The modern Bay formed in response to changing sea level during and following the last major continental glaciation. This history of formation is reflected in the bathymetry, which is characterized by a deep axial channel flanked by broad shallow benches, and in the deeply dissected and invaginated shoreline. Water depths exceed 30 m in the deep channel but overall the Bay is quite shallow with a average depth of 8m.

The drainage basin encompasses 167,000 square km with the Susquehanna River, discharging at the head of the Bay, supplying nearly 50% of the total fresh water input. The Bay is a microtidal system with a tide range of one meter at the mouth, decreasing progressively up-bay to a minimum of less than 30 centimeters in the vicinity of Baltimore, and then increasing to nearly 60 centimeters at the more constricted head of the Bay. Surface salinities range from near zero at the head of the Bay to near 30 ppt at the mouth. The turbidity maximum, located slightly downstream of the landward limit of saline water intrusion, is generally found 30 km from the mouth of the Susquehanna River, although its location varies seasonally with the river discharge.

TEXTURAL CHARACTERISTICS OF BOTTOM SEDIMENTS

Ever since the reconnaissance surveys in the 1950s, the bottom sediments of the Chesapeake Bay have been considered to consist largely of fine grained muds. This assumption prevailed, in part, due to the recognition that the Bay is a microtidal system, has limited fetch inhibiting the

formation of large wind waves, and receives a large total suspended sediment load from upland drainage sources. In fact, one often encounters direct references to the muddy nature of the Bay's sediments in the literature (eg. "Most of the Bay is blanketed with mud. Sand is predominant only...[in limited areas]. While this assumption is certainly true to a first approximation recent surficial sediment sampling has shown that a considerable sand sized component is present in the Bay bottom sediments and, furthermore, that muddy sediments do not necessarily form a uniform blanket on the Bay floor.

In these studies, (Byrne, et.al., 1983; Kerhin, et.al., 1983) stations were located on a 1 km grid in Maryland waters and a 1.4 km offset grid in Virginia waters. At each of the 5924 stations the top 5 cm of sediment was collected and subjected to a complete grain size analysis over the interval of -1 phi to 10 phi (coarse sand to clay). A settling tube was utilized for analysis of the sand sized component and a Coulter Counter for the silts and clay

SEDIMENT DISTRIBUTION

The sediment distribution map clearly illustrates the dominance of sand and silty clay in the Maryland and sand in Virginia part of the Bay. The sands are generally located adjacent to the shoreline and on large shelves around the peninsulas and islands of the Eastern Shore. In most areas the sand directly abuts the silty clay, and sediment populations intermediate to the two end-member populations are absent. These mixed sediment types are generally found as isolated pockets surrounded by either sand or silty clay and not as narrow zones between these two dominant sediment populations.

The sand end member represents high energy wave environments in which movement of materials occurs by traction or saltation along the bed surface. Owing to the energy impinging upon the sediment bed, finer material is either not deposited or is actively removed from the sediments. In contrast, the silty clay end member represents deposition of fine materials from suspension in lower energy environments into which sand-sized materials cannot be carried.

Sediments that plot across the center of the diagram from sand to the finer silty clay are generally assumed to represent a gradual decrease of energy. The zone of mixed sediment apparently reflects the gradual decrease of energy associated with the transition from traction to suspension transport. These mixed sediments may also result from alternating high and low energy events creating intercalated sand and silty clay layers that are subsequently reworked by biogenic processes. In either case a zone of "mixed" sediment types would occur separating the sand and silty clay. The two exceptions are the extreme northern Bay and the Choptank River mouth where the dominant sediments are clayey silts, adjacent to the nearshore sands. In both areas, the accumulation of clayey silts reflects a decreasing-energy regime, local geology, and sediment availability.

Mixed sediments occur as isolated pockets located in the midst of larger sand or silty clay fields. Evidence suggests that many of these pockets represent subaqueous exposures of pre-Holocene deposits, particularly in areas where current or wave activity is sufficiently high to prevent accumulation of modern sediments. Because the textural characteristics of these

sediments do not reflect modern processes, environmental interpretations based upon their grain-size characteristics would be misleading. Of course, anthropogenic activities, particularly dredging and spoil disposal, are not discounted as a possible cause for development of mixed sediments.

Tabulation of the areal extent of sediment types also shows the dominance of the sand and silty clay types. These two sediment types cover over 80 percent of the Bay floor. Silt is the least extensive in the Bay, all silts together covering only 194 square kilometers - less than 7 percent of the Bay. The "mixed" sediment types range from a low of 0.1 percent for sandy clays to a high of approximately 7 percent for the clayey silts.

SEDIMENTATION RATES

In recent years the determination of sedimentation rates in the estuarine environment has become an increasingly important source of data for calculating sediment budgets, determining the fluxes of anthropogenic materials between the sediments and water column, and identifying potential sites of accumulation of toxic materials. Sedimentation rate information is also important from a geologic perspective, because it has often been stated that estuaries are short lived, rapidly filling with sediments once they are formed. In order to adequately describe the resulting stratigraphy and characteristics of the estuarine sedimentary fill the spatial variations in accumulation rates must be established.

In the Chesapeake Bay, as in most estuaries, sedimentation rates have been determined by radionuclide dating of sediment cores returned from the bottom. In the Maryland portion of the Bay Pb-210 rates have been obtained by three separate research groups at 16 locations. The rates range from a low of 0.7 mm/yr to a high of 80 mm/yr. Rates determined by this method assume that the sedimentation rate is relatively constant with no periods of erosion or non-deposition, that no remobilization of the radionuclide has occurred, and that the sediment has not been reworked by either physical processes such as slumping or biogenic activity. Radionuclide derived sedimentation rates can only be determined for fine grained sediments which sorb the isotope, and results cannot be extrapolated to adjacent sediments which contain little or no silt and clay sized particles. Because sandy bottom sediments are areally extensive in the Chesapeake Bay the calculated rates are not valid for much of the system.

Some generalizations may be made. The rate of sediment accumulation tends to be higher in the northern portion of the Bay, north of Kent Island, and close to the Potomac River. In the central portion the lowest rates are observed. Also, rates have a tendency to be higher in the axial channel than on the adjacent channel flanks. However, the range of values observed even between cores located close together indicates that in this highly heterogeneous system extrapolation of the results from an individual core over wide areas of the estuary is risky.

In an attempt to overcome the limitations inherent in the radionuclide methodology sedimentation rates for the mainstem of the Bay have been determined by the method of bathymetric comparisons. Using the original survey sheets produced by the National Oceanographic and Atmospheric Administration water depths were averaged for the earliest

(circa 1850) and the most recent (circa 1950) surveys for which was an adequate density of data points. The results denote the changes in the height of the water column over the time interval spanning the two surveys. The data were rectified to the same mean low water datum by applying correction factors of eustatic sea-level rise (1 mm/yr) and an estimate of recent crustal warping for the Bay region. The latter ranged from over 2.6 mm/yr subsidence in the northern portion of the Bay to 1.0 mm/yr near the Bay mouth.

The bathymetric comparison technique provides an better overview of the sedimentation rates than the nuclide dating because of its ability to provide measurements in the sandy sediments of the Bay, and the capability of developing rate estimates which are representative of large areas of the Bay floor. Due to the nature of the data available from the original sources the Bay was divided into 12 segments based upon basin morphology and bathymetry with the averaged sedimentation rate determined within each segment. In Maryland the average rate of accumulation per year was calculated for both the muddy and sandy sediments within each segment. In Virginia only an average sedimentation rate could be calculated for each segment due to the characteristics of the original data set. The averaged rates shown on Figure 6 are highest in the northern portion of the Bay decline to a low in the upper middle reaches and rise again in the vicinity of the Bay mouth.

The highest sedimentation rate of nearly 0.8 cm/yr occurs in the muddy sediments of the northernmost segment of the Bay. In this area suspended sediments supplied by the Susquehanna River are rapidly deposited on the Bay bottom forming the mixed sand-silt-clays and clayey silts. Rates decline southward through segments 2 and 3 to a minimum approaching zero in the upper middle Bay (segment 4). The sediment distribution map reflects this trend with a broad expanse of silty clays present in segments 2 and 3 where sedimentation rates are still relatively high. In segment 4 where rates are low the sediment distribution begins to show a more discontinuous and patchy nature with many isolated pockets of relatively coarse bottom sediments located in deep waters where little modern sediment is accumulating. Rates rise again in segments 5 and 6, though the sediment distribution map continues to show many isolated and discontinuous sediment types. This suggests that the sites of sediment accumulation are localized in this area. Southward through segment 7 to the Bay mouth rates are variable but remain high reflecting the increasing influence of both the Bay mouth sediment source and resuspension due to tidal currents and wind driven waves in an area where the Bay is relatively wide.

SOURCES OF SEDIMENTS

The sources of sediment to an estuary can be delivered by several different processes: fluvial input mainly as suspended sediment; shoreline erosion; atmospheric dry fall; primary production; erosion of estuarine bottom; and human activity. There is a considerable diversity of information for evaluating these sources of sediments, except for the input of atmospheric dry fall and primary production. However, most discussions of nonpoint sources for sediments are limited to analysis of the inorganic fraction of the total sediment system.

Because the Susquehanna River is the dominant source of fresh water to the Bay,

numerous studies have investigated the input of the suspended sediment load of the Susquehanna River to northern Bay. The estimates of "normal" suspended sediment discharge of the Susquehanna River has varied from a low of 0.6 million metric tons per year to 1.8 million metric ton per year. Major flooding events completely change the character of suspended sediment discharge in the northern Bay. In 1972, Tropical Storm Agnes flood waters discharge an estimated 31 million metric ton of sediment during that events.

BOTTOM SEDIMENT SAMPLING

Field

Aboard the Research Vessel Discovery, fourteen sites in the main Chesapeake Bay were visited in 1996 and 1997 (Table 1). Ten sites were located at major tributaries to the Bay: Rappahannock River in Virginia and the, Potomac, Patuxent and Sassafras Rivers in Maryland. One core site was situated inside the tributary, one at the tributary mouth and one in the main stem of the Bay offshore of the tributary mouth. In the Rappahannock and Sassafras Rivers, the tributary mouth sites were eliminated. Four additional sites were located along a transect from Parker Creek to the Little Choptank River. Two sites near the Parker Creek paleochannel, one in the main channel of the Bay and one in the Little Choptank River. All coring sites were located using Differential Global Positioning System (DGPS).

Short 150 centimeters core samples of the bottom sediment were collected in 6.7 cm diameter cellulose acetate butyrate (CAB) core liners inserted into a Benthos open-barrel gravity corer. The recovered cores were trimmed at the sediment-water interface, capped, and given to the USGS for microfossil analyses. Longer 4-5 meters core samples were collected with a modified Benthos piston core using a standard 6.7 cm diameter cellulose acetate butyrate (CAB) core liner attached with a core catcher and brass cutting shoe. The recovered cores were trimmed at 1.5 meter intervals, measured from the bottom of the core and at the sediment-water interface. The core sections were returned to the laboratory for analyses of physical and granulometric characteristics (Table 2).

Laboratory

In the laboratory, the sediment cores were first X-rayed in their liners with the prints developed using a Xerox 125 xeroradiograph processor. X-rays of cores facilitated recognition of small-scale internal structures, such as clam and worm burrows or tubes, shells, and gas voids. These observations were used to evaluate benthic activity and identify the pre-disposal bottom. On a negative xeroradiographic print, less dense material, such as burrows or gas voids appear darker as compared to denser material, such as shells or sand, which appear lighter.

After the cores were X-rayed, the sediment was extruded from the core liner, split along the axis, photographed, examined, and described. One-half of the piston core was wrapped in plastic wrap for detailed sampling by USGS personnel. The second half of the piston core was scanned for colormetric analysis (Hill and Conkwright, in prep) and logged for physical characteristics and sedimentary structures.

Visual inspection of sediment cores from the Chesapeake Bay shows a broad range of

colors. Varying hues of brown, greenish and bluish grays, gray, and black can be seen. A typical core exhibits a thin top layer, usually brown or light gray, rapidly becoming dark to nearly black, then gradually lightening to some consistent shade of gray. Some cores display alternating light and dark bands. These color bands range between a few millimeters to several centimeters thick. Other cores show irregular patterns such as mottling, and vermiform or lenticular shaped areas.

Table 1 Geographic Coordinates of Piston and Gravity Cores

River Name	Core ID	Latitude NAD 83	Longitude NAD 83	Water Depth Meters	Date
Potomac	PTMC 2-1	37 58 24.0	76 13 44.0	13.20	9/17/96
Potomac	PTMC 2-2	37 58 24.0	76 13 44.0	13.20	9/19/96
Potomac	PTMC 3-1	38 1 40.20	76 13 12.7	23.10	9/25/96
Potomac	PTMC 3-G	38 1 40.10	76 13 12.7	20.00	9/19/96
Potomac	PTMC 3-2	38 1 36.70	76 13 11.6	23.10	9/25/96
Potomac	PTMC 3-G-2	38 1 36.70	76 13 11.6	24.10	9/25/96
Parker Creek	PRCK 3-1	38 32 38.0	76 25 37.1	24.30	10/9/96
Parker Creek	PRCK 3-2	38 32 38.0	76 25 37.1	24.30	10/9/96
Parker Creek	PRCK 1-1	38 32 51.9	76 29 42.7	10.70	9/23/96
Parker Creek	PRCK 1-2	38 32 51.9	76 29 42.7	10.70	9/23/96
Parker Creek	PRCK 2-1	38 33 9.30	76 27 34.4	11.40	5/7/97
Patuxent	PTXT 1-1	38 18 34.9	76 27 12.5	16.50	9/18/96
Patuxent	PTXT 1-2	38 18 34.9	76 27 12.5	16.50	9/18/96
Patuxent	PTXT 1-3	38 18 34.9	76 27 12.5	16.50	9/18/96
Patuxent	PTXT 1-G	38 18 34.9	76 27 11.4	16.30	9/19/96
Patuxent	PTXT 2-1	38 19 35.0	76 23 32.9	10.00	9/18/96
Patuxent	PTXT 2-2	38 19 34.4	76 23 32.9	10.00	9/18/96
Patuxent	PTXT 2-3	38 19 34.7	76 23 33.1	11.50	9/18/96
Patuxent	PTXT 2-G	38 19 35.1	76 23 32.8	11.40	9/19/96
Patuxent	PTXT 2-G-2	38 19 34.7	76 23 33.1	11.50	9/20/96
Patuxent	PTXT 3-1	38 20 0.00	76 18 34.8	22.50	9/20/96
Patuxent	PTXT 3-2	38 20 0.00	76 18 34.8	22.50	9/20/96
Patuxent	PTXT 3-G	38 20 0.00	76 18 34.8	22.50	9/20/96

River Name	Core ID	Latitude NAD 83	Longitude NAD 83	Water Depth Meters	Date
Parker Creek	PRCK 1-G	38 32 51.9	76 28 42.7	10.70	9/26/96
Parker Creek	PRCK 2-G	38 33 9.30	76 27 34.4	11.40	9/26/96
Parker Creek	PRCK 3-G	38 32 38.2	76 25 37.2	24.30	9/26/96
Little Choptank	LCPTK 1-1	38 31 29.5	76 18 11.9	13.90	9/26/96
Little Choptank	LCPTK 1-2	38 31 29.5	76 18 11.9	13.90	9/26/96
Little Choptank	LCPTK 1-G	38 31 29.5	76 18 11.9	13.90	9/26/96
Rappahannock	RAPRV 1-1	37 35 53.3	76 18 27.6	19.70	9/24/96
Rappahannock	RAPRV 1-2	37 35 53.3	76 18 27.6	19.70	9/24/96
Rappahannock	RAPRV 1-G	37 35 53.3	76 18 27.6	19.70	9/24/96
Rappahannock	RAPRV 2-1	37 32 28.2	76 10 21.9	11.50	9/24/96
Rappahannock	RAPRV 2-2	37 32 28.2	76 10 21.9	11.50	9/24/96
Rappahannock	RAPRV 2-G	37 32 28.2	76 10 21.9	11.50	9/24/96
Potomac	PTMC 1-1	38 1 50.30	76 22 40.6	19.00	9/19/96
Potomac	PTMC 1-2	38 1 50.30	76 22 40.6	19.00	9/19/96
Potomac	PTMC 1-G	38 1 50.30	76 22 40.6	19.00	9/17/96

Table 2 Piston Core Lengths

River Name	Core ID	Total Length	Top	Middle	Bottom
Patuxent	PTXT 1-3	199	75	124	0
Patuxent	PTXT 2-3	417	110	153	154
Patuxent	PTXT 3-2	432	133	153	146
Potomac	PTMC 3-2	452	150	152	150
Potomac	PTMC 2-2	354	57	150	147
Potomac	PTMC 1-2	422	122	150	150
Rappahannock	RAPRV 1-2	232	86	146	0
Rappahannock	RAPRV 2-2	405	109	150	146
Rappahannock	RAPRV 3-2	452	145	154	153
Little Choptank	LCPTK 1-1	455	147	153	155
Parker Creek	PRCK 1-2	315	107	77	131
Parker Creek	PRCK 3-2	452	145	154	153
Sassafras River	SASS 1-1	407	109	151	147
Sassafras River	SASS 2-2	383	95	153	134
Parker Creek	PRCK 2-1	426	120	153	153

Grain size, mineralogy, carbon content, organic matter, and water content partially determine the color and intensity of light reflected from sediments. The presence of sulfur minerals greatly affects the color of fine grained, cohesive sediments. Chemical analysis of fine grained, cohesive sediments from the Chesapeake Bay indicate that the major sulfur minerals present are pyrite, monosulfide species and native sulfur. Further analysis shows a distinct relationship between the ratio of pyrite to monosulfides and the color of these sediments. Light gray sediments have a high pyrite to monosulfide ratio, while dark sediments have low pyrite to monosulfide ratio. A linear relationship exists between the pyrite to monosulfide ratio (p/m ratio) and the intensity of light reflected from the sediments. By measuring the reflection intensity along the entire length of a carefully cross-sectioned core and chemically analyzing the sulfur mineralogy in a few subsamples, the sulfur mineralogy of the entire core can be determined.

The core scanner is designed to measure the intensity of selected light wavelengths reflected from the surface of sediment cores. The scanner continuously records the reflection intensity of the sediments and the depth down-core of the reflection measurements. Scanner data can be sent to an X-Y recorder and/or and analog to digital converter for digital storage.

The sediment was subsequently subsampled and analyzed for water content, porosity, bulk density, and on selected subsamples, grain-size. Datable materials such as shell was also sampled and forwarded to USGS for Carbon 14 dating. Analyses were conducted according to MGS standard techniques as outlined in Kerhin and others (1988). Two homogeneous splits of each sample were processed, one for bulk property analyses and the other for grain-size characterization. Analyses were performed as soon as possible after sample collection, and all samples were refrigerated in sealed Whirl-Pak plastic bags prior to analysis.

Water content was measured at selected intervals from the core upon extrusion from the liner. Samples were divided into weighed 30 g portions, dried at 65°C, and then reweighed. Water content was calculated as the percentage of water weight to the total weight of wet sediment, as follows:

$$\%H_2O = \left(\frac{W_w}{W_t}\right) \times 100 \quad (1)$$

where W_w is the weight of water, and W_t is the weight of wet sediment.

The water content may be underestimated because of water being lost from the sediment during the time interval between collection and extrusion of the core. Recently deposited dredged sediments, contained within the core liner, exhibit a measurable amount of dewatering between the time of collection and analysis, resulting in compaction. The amount of water expressed from the sediment subsequent to collection can be calculated by measuring the change in core length prior to extrusion. Water contents calculated in the laboratory were corrected by

assuming that this compaction occurred evenly throughout the thickness of the most recent dredged sediment layer. The water content values reported for the sampling locations represent the corrected average of the interval samples downcore.

The precision of water content measurements was determined by calculating the relative standard deviation. For sediment samples collected and analyzed in this manner, the relative standard deviation for percent water content was determined to be 4.46 percent (Halka and Panageotou, 1993). The standard deviation (σ) for any particular water content may be calculated as:

$$\sigma_{H_2O} = \frac{\%H_2O}{100} \times 4.46 \quad (2)$$

Bulk density (ρ_b) and porosity (P) were calculated from water content utilizing equations (3) and (4) by assuming an average grain density (ρ_s) of 2.72 g/cm³ and saturation of voids with water of density $\rho_w = 1.0$ g/cm³. This method was adopted from the work of Bennett and Lambert (1971):

$$\rho_b = \frac{W_t}{W_d/2.72 + W_w} \quad (3)$$

where W_d is the weight of dry sediment.

$$P = \rho_s \frac{\%H_2O}{\rho_s \%H_2O + \rho_w (1 - \%H_2O)} \quad (4)$$

The amount of volumetric reduction (V_Δ) attributable to *in situ* dewatering (consolidation) of the deposit was determined by calculating the volume change over time resulting from the reduction in porosity in the collected cores. Porosity was calculated from the average water contents of the cores according to equation (4). Over a period of time the volume change due to consolidation can be calculated utilizing equation (5):

$$V_\Delta = \frac{1 - P_i}{1 - P_f} \times 100 \quad (5)$$

where P_i is the initial porosity at time one, and P_f is the final porosity at time two. The amount of erosion which has occurred can then be estimated by first calculating the total sediment volume change from acoustic reflection or bathymetric analyses, and subtracting the volume determined to be due to *in situ* dewatering.

Grain size analysis consisted of cleaning the samples in solutions of 10 percent hydrochloric acid and 15 percent hydrogen peroxide with subsequent rinsing with deionized water. This process removed soluble salts, carbonates, and organic matter that could interfere with the disaggregation of the individual grains. The samples were then treated with a 0.26 percent solution of the dispersant sodium hexametaphosphate ((NaPO₃)₆) to ensure that individual grains did not reaggregate during analysis.

The separation of sand and silt-clay portions of the sample was accomplished by wet-sieving through a 4-phi mesh sieve (0.0625 mm, U.S. Standard Sieve #230). The sand fraction was dried and weighed. The finer silt and clay sized particles were suspended in a 1000 ml cylinder in a solution of 0.26 percent sodium hexametaphosphate. The suspension was agitated and, at specified times thereafter, 20 ml pipette withdrawals were made (Carver, 1971; Folk, 1974). The rationale behind this process is that larger particles settle faster than smaller ones. By calculating the settling velocities for different sized particles, times for withdrawal can be determined at which all particles of a specified size will have settled past the point of withdrawal. Sampling times were calculated to permit the determination of the amount of silt (4 phi) and clay sized (8 phi) particles in the suspension. Withdrawn samples were dried at 60°C and weighed. From these data the percentages by dry weight of sand, silt, and clay were calculated for each sample and classified according to Shepard's (1954) nomenclature (Figure 3).

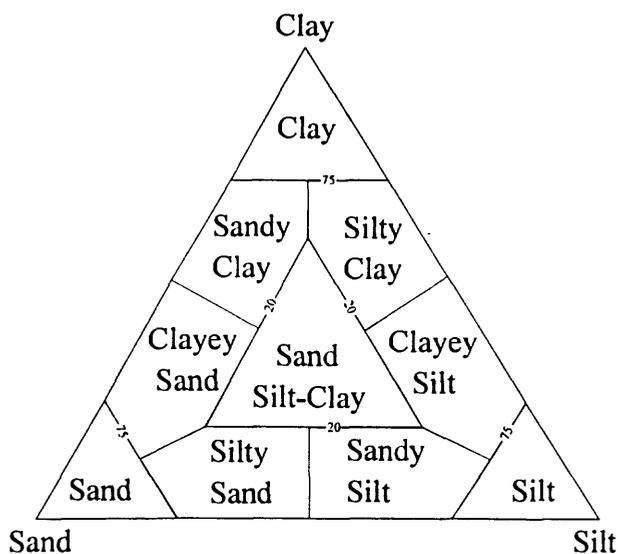


Figure 1. Shepard's (1954) classification of sediment types.

Table 3 Types of samples from Piston Cores at each depth interval

Core ID	Sample Type	Interval
PRCK 2-1	Maine	46-50
PRCK 2-1	Maine	92-96
PRCK 2-1	Maine	144-148
PRCK 2-1	Maine	188-192
PRCK 2-1	Maine	228-266
PRCK 2-1	Maine	262-266
PRCK 2-1	Maine	300-304
PRCK 2-1	Maine	340-344
PRCK 2-1	Maine	380-384
PRCK 2-1	Maine	422-426
PTMC 1-2	Sediment	0-4
PTMC 1-2	Sediment	16-20
PTMC 1-2	Sediment	40-44
PTMC 1-2	Sediment	70-74
PTMC 1-2	Sediment	110-114
PTMC 1-2	Sediment	131-135

PTMC 2-2	Sediment	160-164
PTMC 1-2	Sediment	187-191
PTMC 1-2	Sediment	210-214
PTMC 1-2	Sediment	230-234
PTMC 1-2	Sediment	260-264
PTMC 1-2	Sediment	286-290
PTMC 1-2	Sediment	306-310
PTMC 1-2	Sediment	336-340
PTMC 1-2	Sediment	382-386
PTMC 1-2	Sediment	414-418
PTMC 2-2	Sediment	4-8
PTMC 2-2	Sediment	20-24
PTMC 2-2	Sediment	40-44
PTMC 2-2	Sediment	50-54
PTMC 2-2	Sediment	62-63
PTMC 2-2	Sediment	90-94
PTMC 2-2	Sediment	116-120

PTMC 2-2	Sediment	142-146
PTMC 2-2	Sediment	178-182
PTMC 2-2	Sediment	210-214
PTMC 2-2	Sediment	230-234
PTMC 2-2	Sediment	284-288
PTMC 2-2	Sediment	296-300
PTMC 2-2	Sediment	326-330
PTMC 2-2	Sediment	346-350
PTMC 3-2	Sediment	2-6
PTMC 3-2	Sediment	20-24
PTMC 3-2	Sediment	42-46
PTMC 3-2	Sediment	76-80
PTMC 3-2	Sediment	106-110
PTMC 3-2	Sediment	128-132
PTMC 3-2	Sediment	156-160
PTMC 3-2	Sediment	200-204
PTMC 3-2	Sediment	236-240
PTMC 3-2	Sediment	260-264
PTMC 3-2	Sediment	282-286

PTMC 3-2	Sediment	306-310
PTMC 3-2	Sediment	334-338
PTMC 3-2	Sediment	356-360
PTMC 3-2	Sediment	394-398
PTMC 3-2	Sediment	418-422
PTMC 3-2	Sediment	446-450
PTXT 3-2	Sediment	10-14
PTXT 3-2	Sediment	32-36
PTXT 3-2	Sediment	76-80
PTXT 3-2	Sediment	124-128
PTXT 3-2	Sediment	170-174
PTXT 3-2	Sediment	208-212
PTXT 3-2	Sediment	248-252
PTXT 3-2	Sediment	272-276
PTXT 3-2	Sediment	322-326
PTXT 3-2	Sediment	336-340
PTXT 3-2	Sediment	356-360
PTXT 3-2	Sediment	392-396
PTXT 3-2	Sediment	428-432

PTXT 3-2	Sediment	362-382
PTXT 1-3	Sediment	4-8
PTXT 1-3	Sediment	34-38
PTXT 1-3	Sediment	42-46
PTXT 1-3	Sediment	64-68
PTXT 1-3	Sediment	86-90
PTXT 1-3	Sediment	104-108
PTXT 1-3	Sediment	122-126
PTXT 1-3	Sediment	144-148
PTXT 1-3	Sediment	166-170
PTXT 1-3	Sediment	184-188
PTXT 1-3	Sediment	194-199
RAPRV 2-2	Sediment	4-8
RAPRV 2-2	Sediment	16-20
RAPRV 2-2	Sediment	34-38
RAPRV 2-2	Sediment	90-94
RAPRV 2-2	Sediment	126-130
RAPRV 2-2	Sediment	164-168
RAPRV 2-2	Sediment	200-204

RAPRV 2-2	Sediment	250-254
RAPRV 2-2	Sediment	290-294
RAPRV 2-2	Sediment	340-344
RAPRV 2-2	Sediment	364-368
RAPRV 2-2	Sediment	386-390
RAPRV 2-2	Sediment	396-400
RAPRV 2-2	Sediment	400-404
RAPRV 1-2	Sediment	2-6
RAPRV 1-2	Sediment	14-18
RAPRV 1-2	Sediment	20-24
RAPRV 1-2	Sediment	62-66
RAPRV 1-2	Sediment	96-100
RAPRV 1-2	Sediment	116-120
RAPRV 1-2	Sediment	150-154
RAPRV 1-2	Sediment	196-200
RAPRV 1-2	Sediment	226-230
PRCK 3-2	Sediment	4-8
PRCK 3-2	Sediment	58-62
PRCK 3-2	Sediment	78-82

PRCK 3-2	Shells	121-125
PRCK 3-2	Sediment	138-142
PRCK 3-2	Sediment	156-160
PRCK 3-2	Sediment	184-188
PRCK 3-2	Sediment	220-224
PRCK 3-2	Sediment	248-252
PRCK 3-2	Sediment	266-270
PRCK 3-2	Sediment	288-292
PRCK 3-2	Sediment	336-340
PRCK 3-2	Sediment	368-372
PRCK 3-2	Sediment	380-384
PRCK 3-2	Sediment	406-410
PRCK 3-2	Sediment	418-122
PRCK 3-2	Sediment	434-438
PTXT 2-3	Sediment	4-8
PTXT 2-3	Sediment	26-30
PTXT 2-3	Sediment	48-52
PTXT 2-3	Sediment	68-72
PTXT 2-3	Sediment	72-76

PTXT 2-3	Sediment	98-102
PTXT 2-3	Sediment	132-136
PTXT 2-3	Sediment	166-170
PTXT 2-3	Sediment	214-218
PTXT 2-3	Sediment	234-238
PTXT 2-3	Sediment	238-242
PTXT 2-3	Sediment	242-246
PTXT 2-3	Shells	246-252
PTXT 2-3	Sediment	252-256
PTXT 2-3	Sediment	276-280
PTXT 2-3	Sediment	300-304
PTXT 2-3	Sediment	330-334
PTXT 2-3	Sediment	348-352
PTXT 2-3	Sediment	378-382
PTXT 2-3	Sediment	402-406
PTXT 2-3	Shells	343-345
PTXT 2-3	Shells	409-413
PTXT 3-2	Shells	350-356
PTMC 1-2	Shells	196-200

LCPTK 1-1	Sediment	4-8
LCPTK 1-1	Sediment	16-20
LCPTK 1-1	Sediment	28-32
LCPTK 1-1	Sediment	34-38
LCPTK 1-1	Sediment	44-48
LCPTK 1-1	Sediment	60-64
LCPTK 1-1	Sediment	66-70
LCPTK 1-1	Sediment	132-136
LCPTK 1-1	Sediment	138-142
LCPTK 1-1	Sediment	166-170.5
LCPTK 1-1	Sediment	170.5-174
LCPTK 1-1	Sediment	190-194
LCPTK 1-1	Sediment	211-213
LCPTK 1-1	Sediment	213-215
LCPTK 1-1	Sediment	215-217
LCPTK 1-1	Sediment	240-244
LCPTK 1-1	Shells	250-252
LCPTK 1-1	Sediment	252-256
LCPTK 1-1	Sediment	290-294

LCPTK 1-1	Sediment	312-316
LCPTK 1-1	Sediment	358-362
LCPTK 1-1	Sediment	388-392
LCPTK 1-1	Sediment	410-414
LCPTK 1-1	Sediment	420-424
LCPTK 1-1	Sediment	428-432
LCPTK 1-1	Sediment	434-438
LCPTK 1-1	Sediment	438-442
LCPTK 1-1	Sediment	442-446
PRCK 1-2	Sediment	4-8
PRCK 1-2	Sediment	28-32
PRCK 1-2	Sediment	40-44
PRCK 1-2	Sediment	58-62
PRCK 1-2	Sediment	80-84
PRCK 1-2	Sediment	112-116.5
PRCK 1-2	Sediment	116.5-120
PRCK 1-2	Sediment	146-150
PRCK 1-2	Sediment	154-158
PRCK 1-2	Sediment	160-164

PRCK 1-2	Sediment	180-184
PRCK 1-2	Sediment	224-228
PRCK 1-2	Sediment	282-286
PRCK 1-2	Sediment	286-290
PRCK 1-2	Sediment	304-308
PRCK 1-2	Sediment	310-314
PTXT 2-3	Shells	40-42
PTXT 2-3	Shells	87-91
PTXT 2-3	Shells	409-413
LCPTK 1-1	Shells	214-216
LCPTK 1-1	Shells	442-446
LCPTK 1-1	Shells	452
PRCK 3-2	Shells	257-262
PRCK 3-2	Shells	336-340
PRCK 1-2	Shells	91-93
PRCK 1-2	Organics	180-183
PRCK 1-2	Oysters	317
PTXT 1-3	Shells	84
PTXT 1-3	Organics/Wood	116

RAPRV 1-2	Shells	122-127
PTXT 3-2	Shells	350-356
PTXT 3-2	Shells	360-364
PTXT 3-2	Shells	364-368
PTXT 3-2	Shells	372-376
PTXT 3-2	Shells	376-380
PTXT 3-2	Shells	380-384
PTXT 3-2	Shells	384-388
PTXT 3-2	Shells	388-392
PTXT 3-2	Shells	368-372
PTXT 3-2	Shells	396-400
PTXT 3-2	Shells	400-404
PTXT 3-2	Shells	404-408
PTXT 3-2	Shells	408-412
PTXT 3-2	Shells	412-416
PTXT 3-2	Shells	416-420
PTXT 3-2	Shells	420-424
PTMC 3-2	Shells	407-414
PTMC 2-2	Shells	157-163

PTXT 1-3	Shells	30-34
PTMC 3G	Shells	40-42
PTMC 3G	Shells	55-57
PTMC 1G	Shells	75-77
PRCK 1G	Shells	54
PRCK 1G	Shells	85-87
PTXT 2G2	Shells	5-7
PTXT 2G2	Shells	25-27
PTXT 2G2	Shells	65-67
LCPTK 1G	Shells	65-67
PTXT 1G	Shells	60
PRCK 2-1	Sediment	8-12
PRCK 2-1	Sediment	38-42
PRCK 2-1	Sediment	42-46
PRCK 2-1	Sediment	80-84
PRCK 2-1	Sediment	88-92
PRCK 2-1	Sediment	140-144
PRCK 2-1	Sediment	184-188
PRCK 2-1	Sediment	224-228

PRCK 2-1	Sediment	258-262
PRCK 2-1	Sediment	296-300
PRCK 2-1	Sediment	336-340
PRCK 2-1	Sediment	376-380
PRCK 2-1	Sediment	418-422
SASS 1-1	Sediment	10-14
SASS 1-1	Sediment	42-46
SASS 1-1	Sediment	46-50
SASS 1-1	Sediment	50-54
SASS 1-1	Sediment	102-106
SASS 1-1	Sediment	122-126
SASS 1-1	Sediment	160-164
SASS 1-1	Sediment	216-220
SASS 1-1	Sediment	228-232
SASS 1-1	Sediment	250-254
SASS 1-1	Sediment	310-314
SASS 1-1	Sediment	360-364
SASS 1-1	Sediment	386-390
SASS 1-1	Sediment	404-408

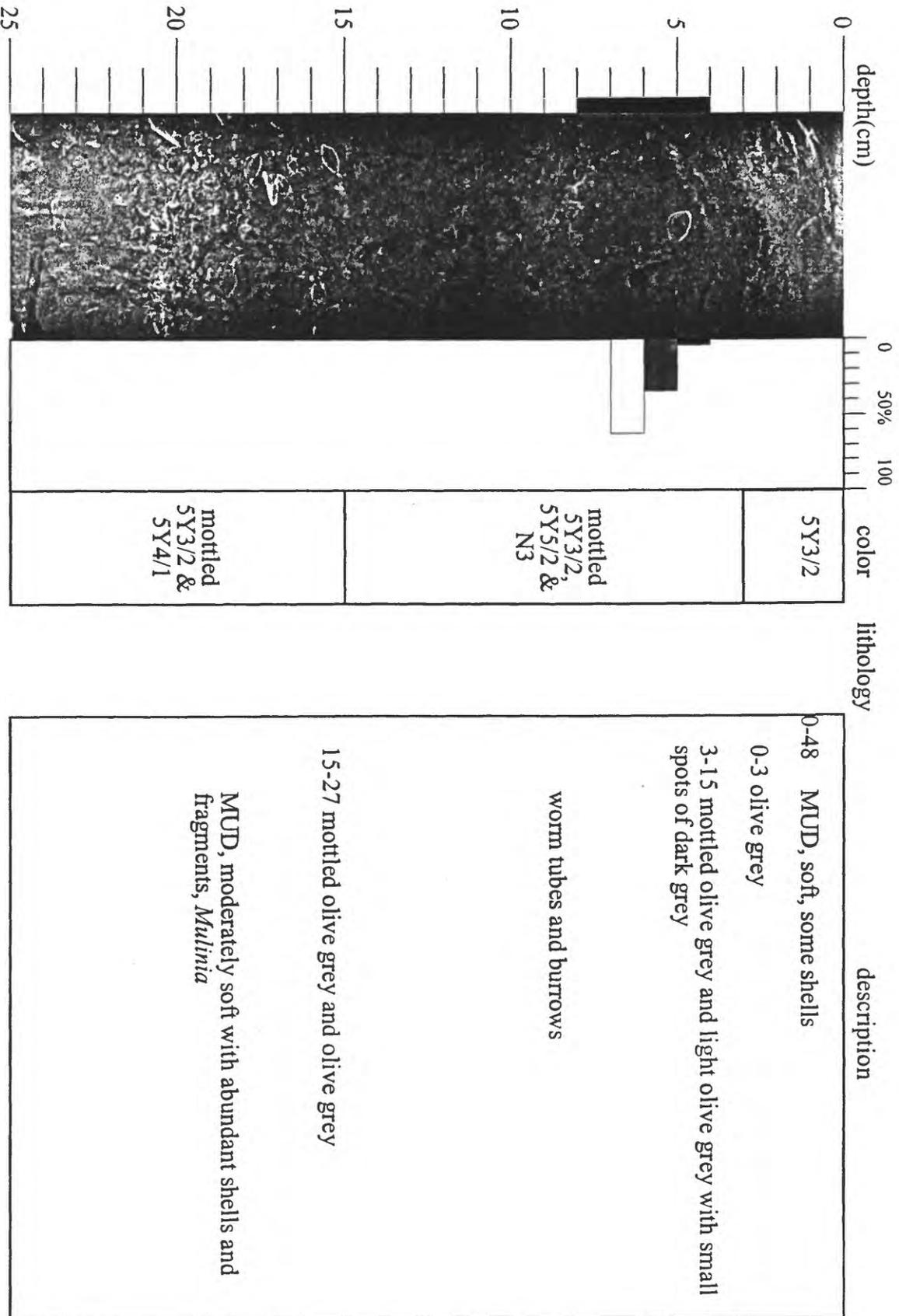
SASS 2-2	Sediment	18-21.5
SASS 2-2	Sediment	26-30
SASS 2-2	Sediment	40-44
SASS 2-2	Sediment	46-50
SASS 2-2	Sediment	80-84
SASS 2-2	Sediment	110-114
SASS 2-2	Sediment	160-164
SASS 2-2	Sediment	170-174
SASS 2-2	Sediment	192-196
SASS 2-2	Sediment	214-218
SASS 2-2	Sediment	250-254
SASS 2-2	Sediment	254-258
PRCK 2-1	Shell	64-68
PRCK 2-1	Shell	84-88
SASS 2-2	Sediment	314-318
SASS 2-2	Sediment	336-340
SASS 2-2	Sediment	340-343
SASS 2-2	Sediment	343-348
SASS 2-2	Sediment	370-374

PRCK 1-2	Sediment	158-160
SASS 2-2	Shell	121-122
PRCK 2-1	Shell	64-68
PRCK 2-1	Organic	201-202
SASS 1-1	Maine	118-122
SASS 1-1	Maine	156-160
SASS 2-2	Organic	130-132
SASS 2-2	Shell/wood	318-320
SASS 2-2	Wood	341-342
PTMC 1-2	Shell	161
PTMC 3-2	Shell	141
SASS 1-1	Maine	212-126
SASS 1-1	Maine	246-250
SASS 1-1	Maine	306-310
SASS 1-1	Maine	356-360
SASS 1-1	Maine	382-386
SASS 1-1	Maine	400-404
PRCK 2-1	Maine	12-16

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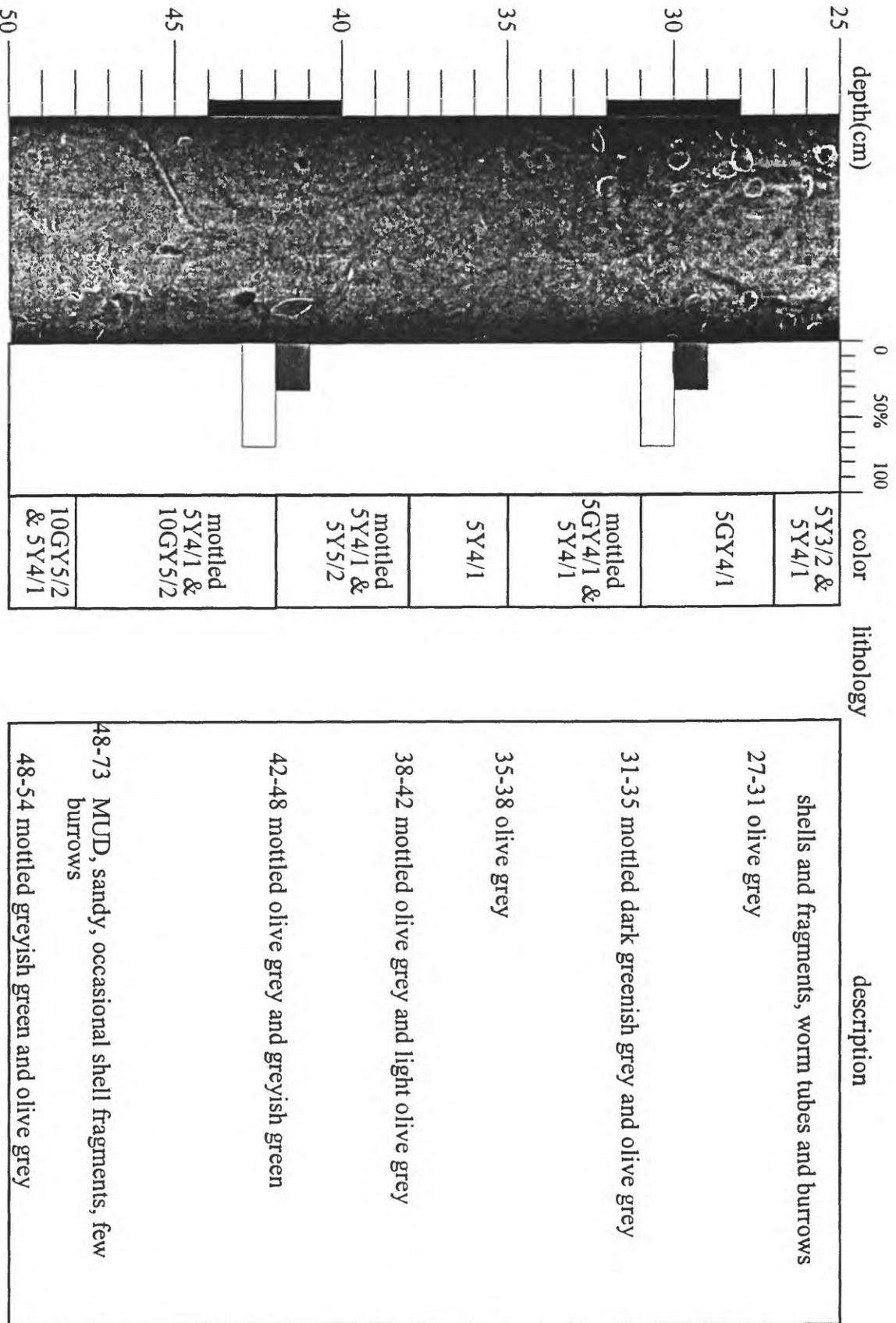
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Core PRCK 1-2



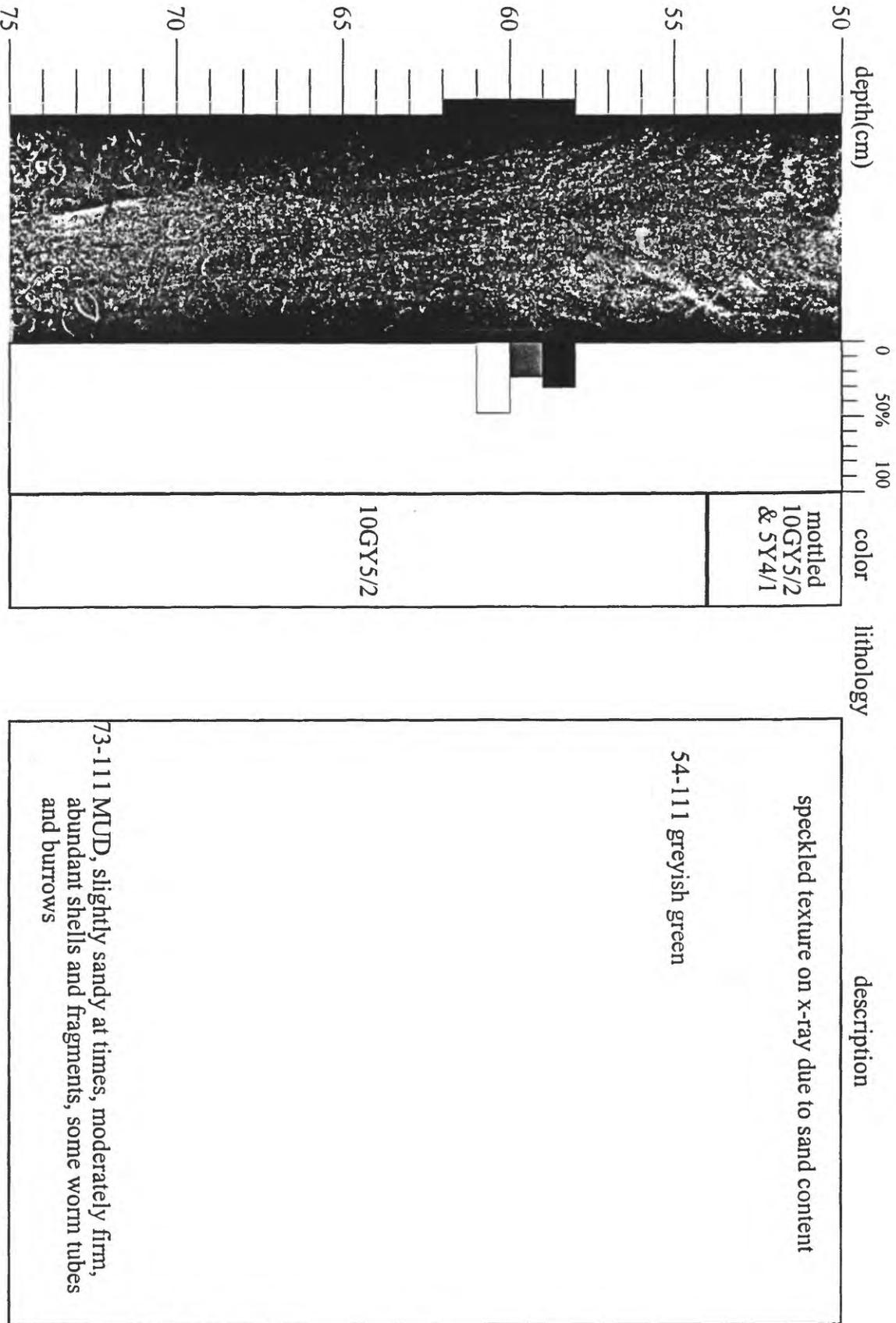
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Core PRCK 1-2



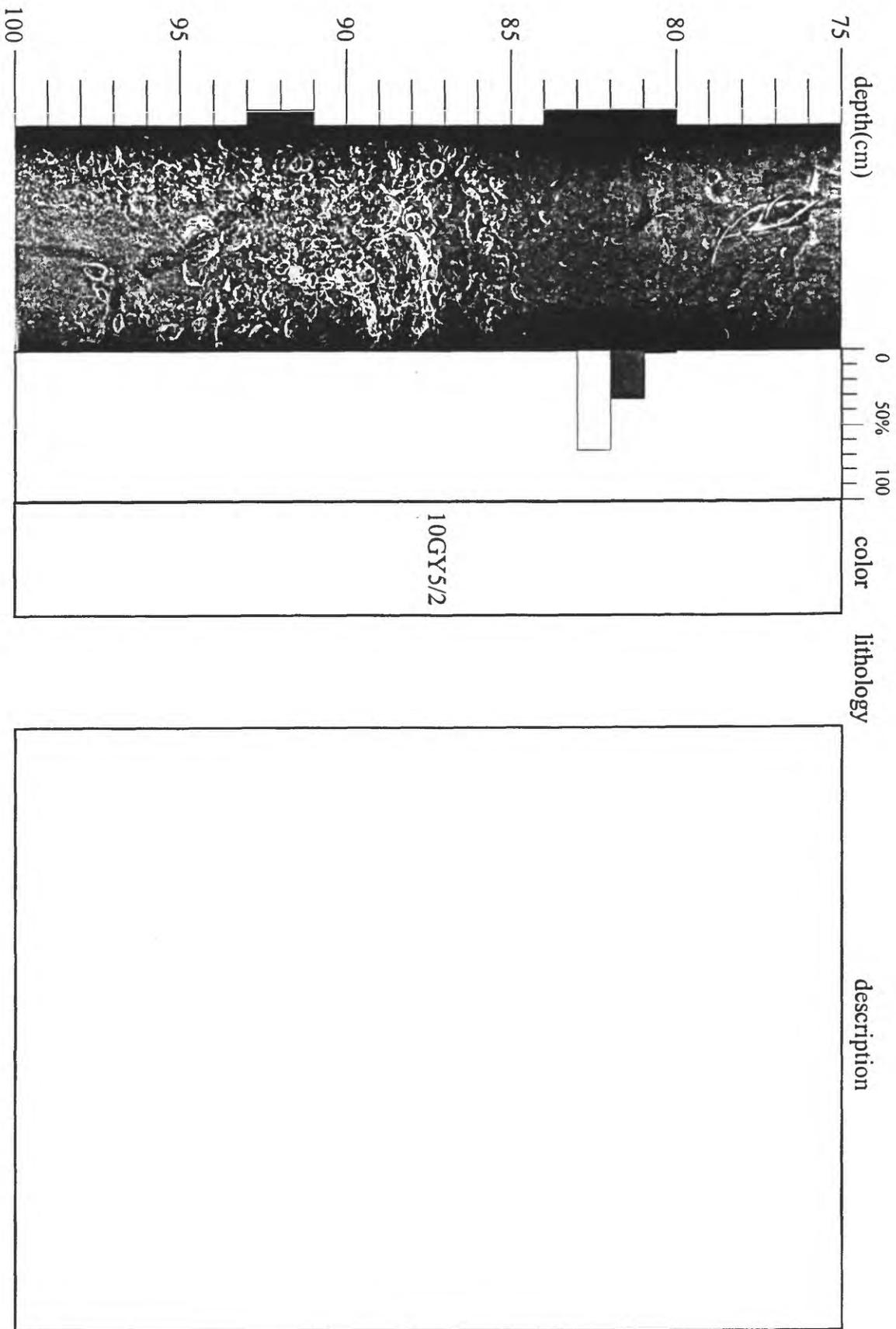
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Core PRCK 1-2



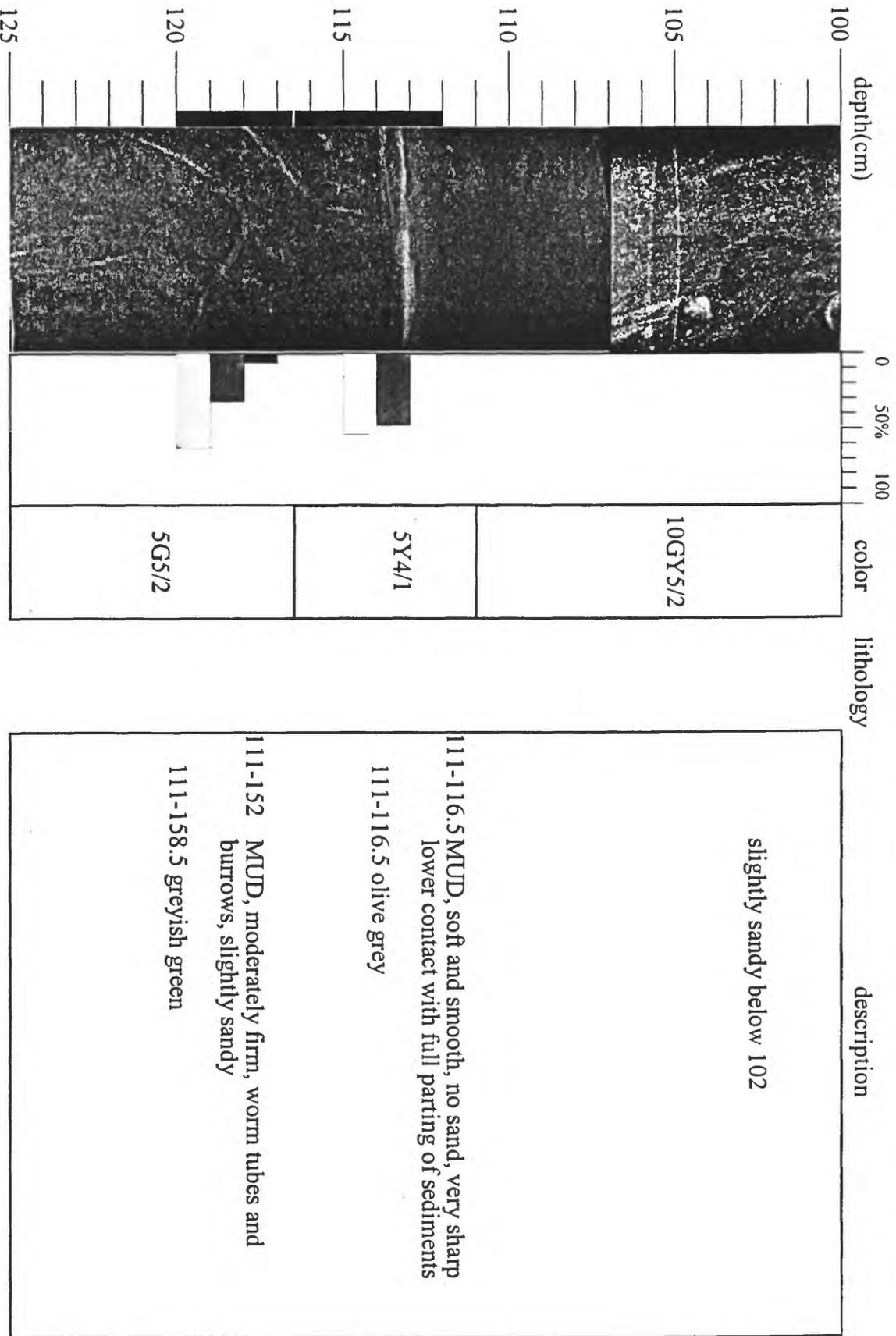
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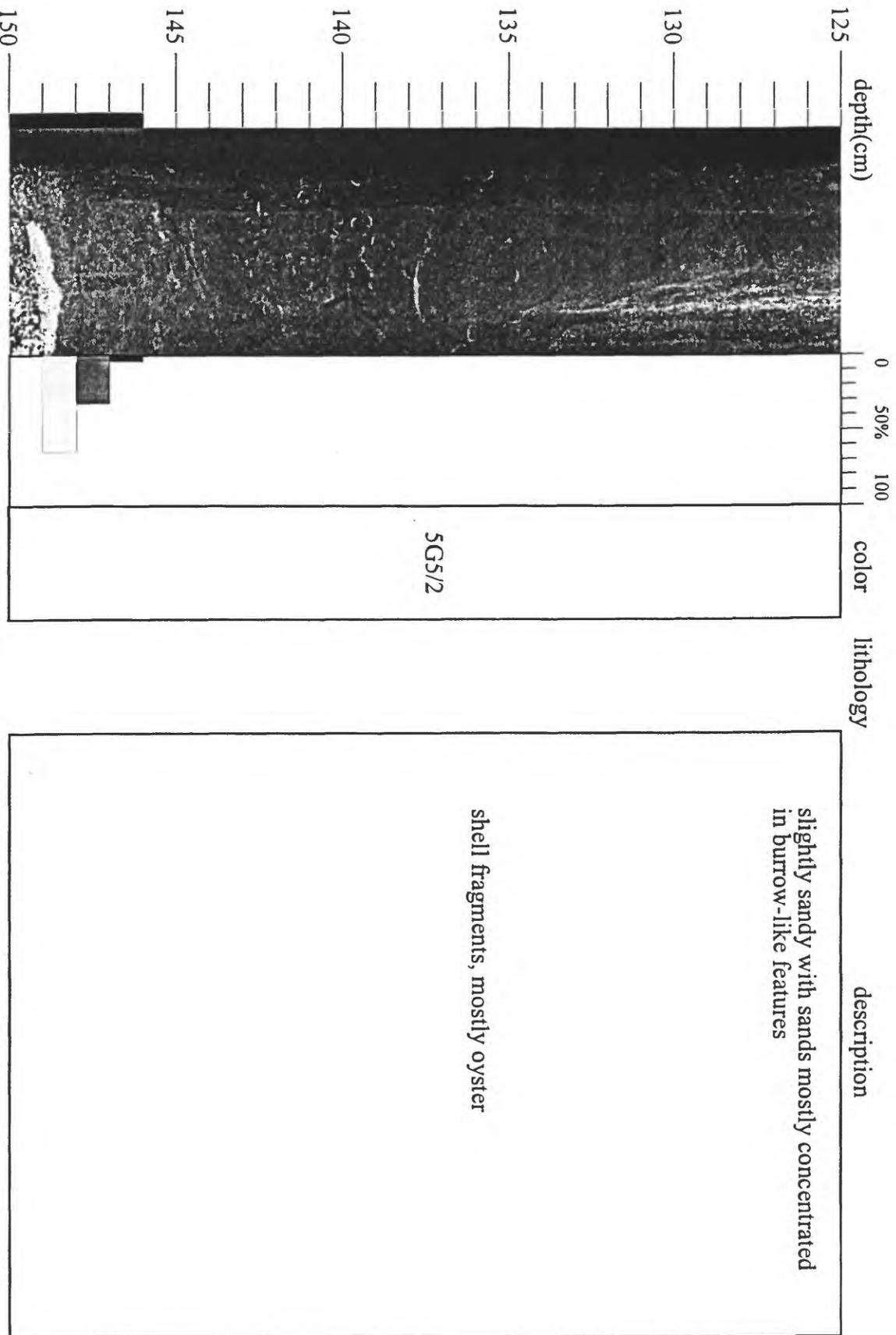
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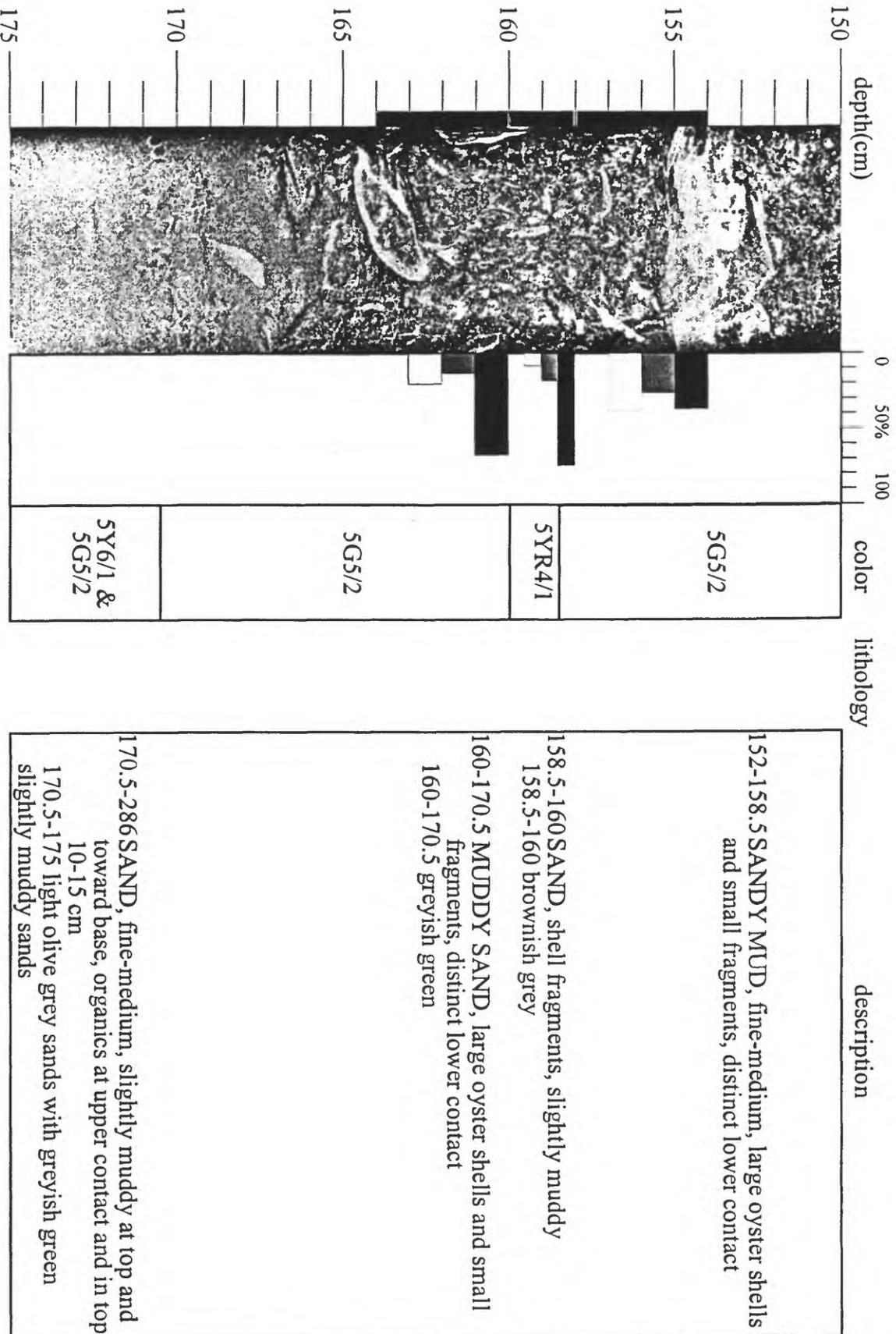
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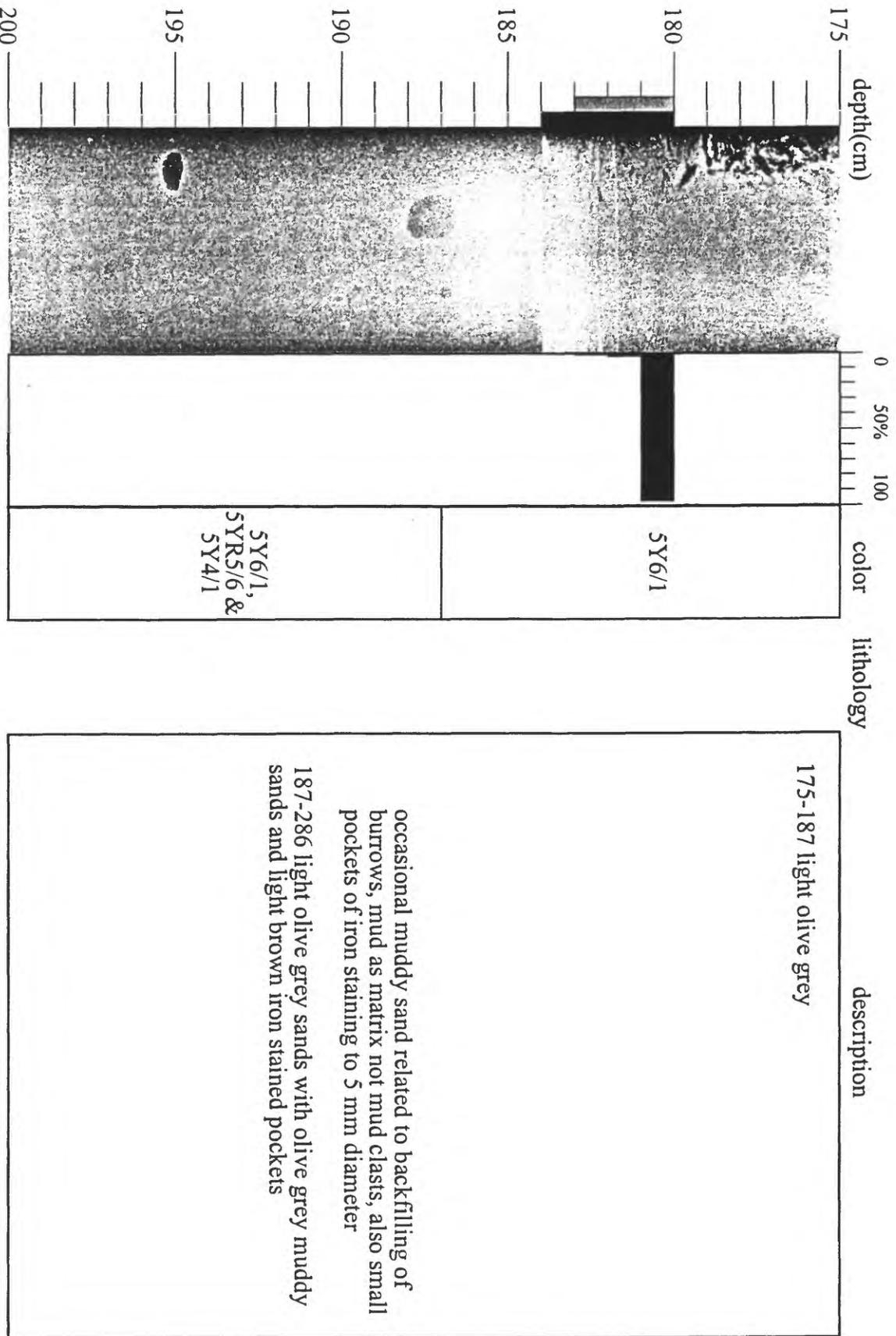
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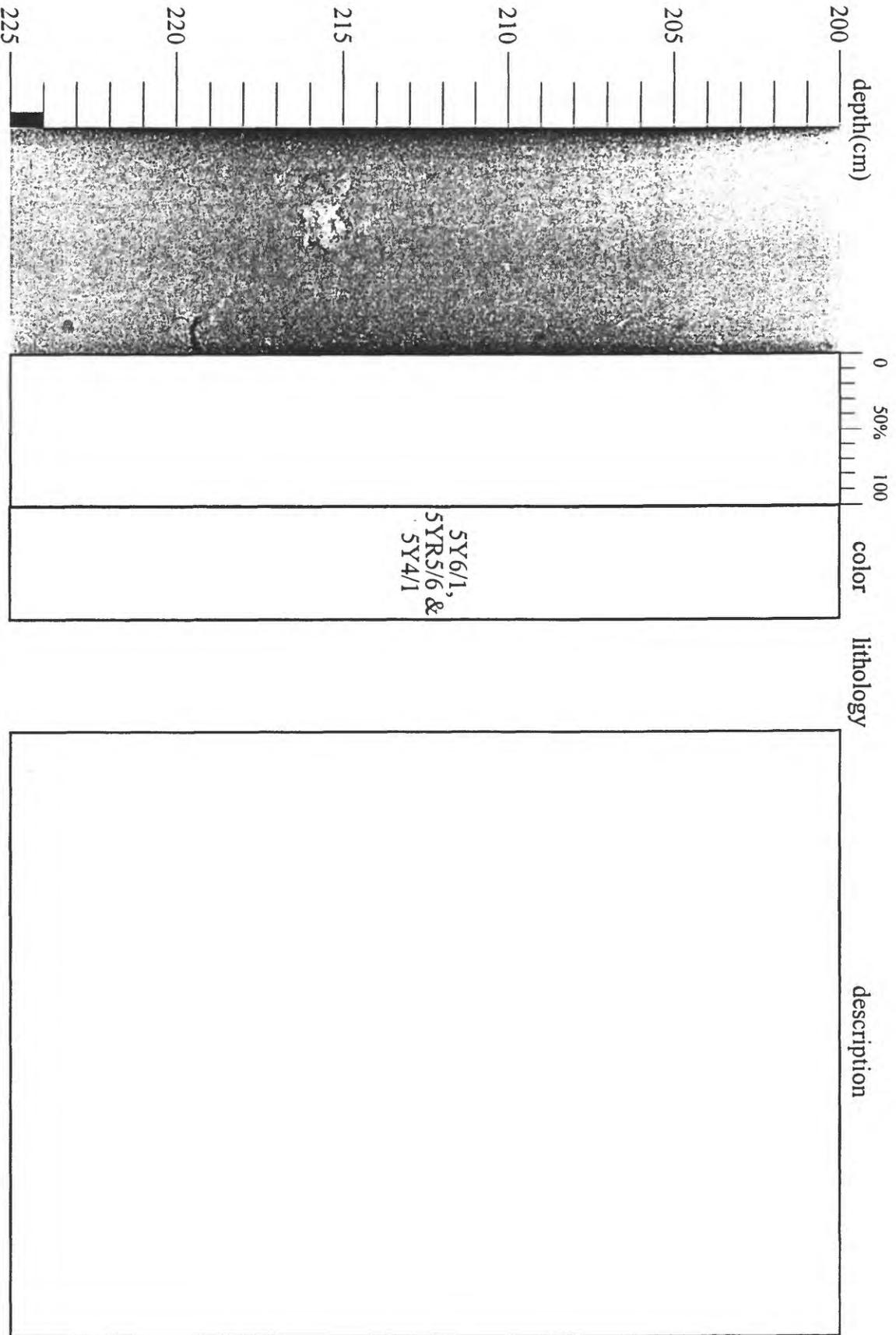
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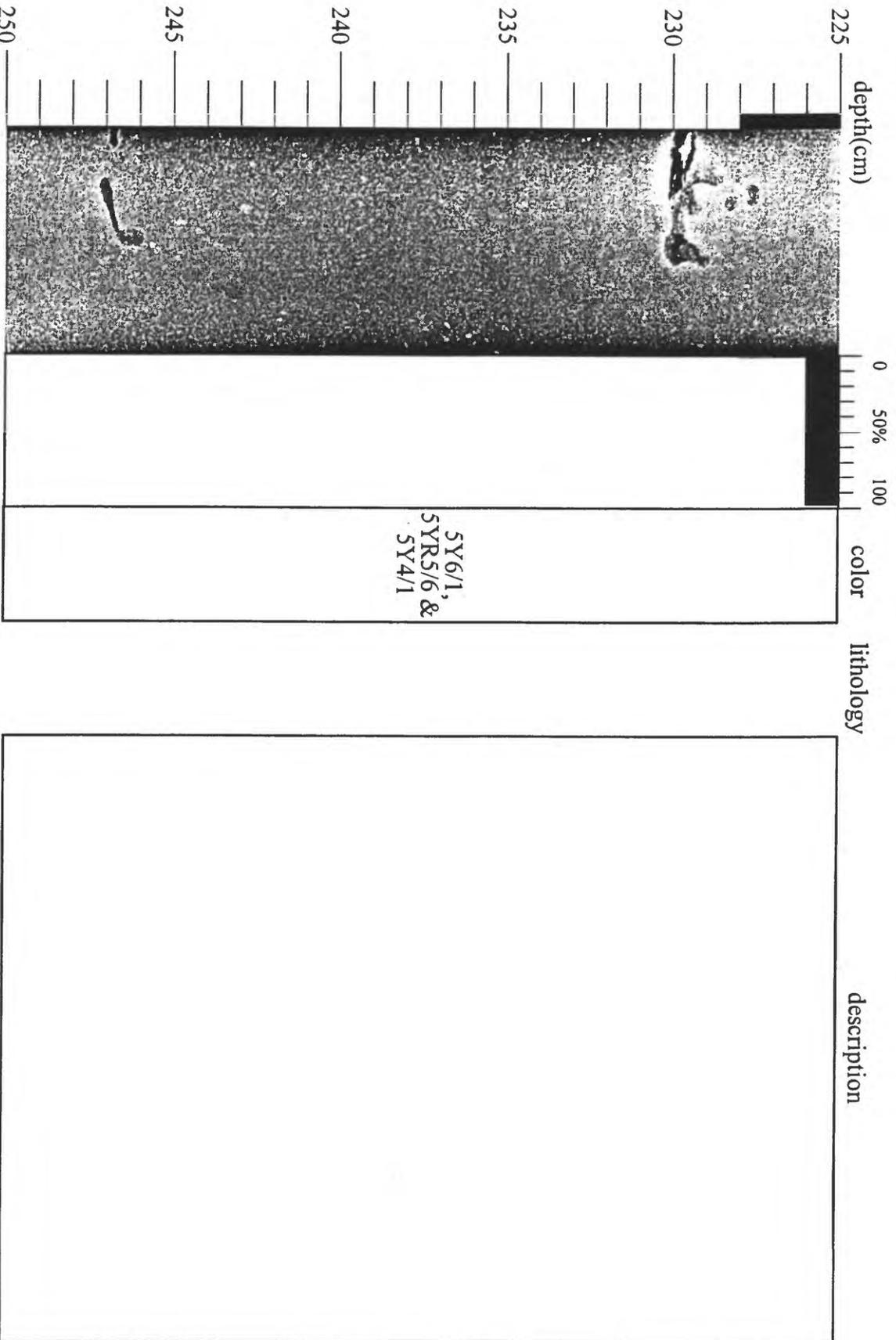
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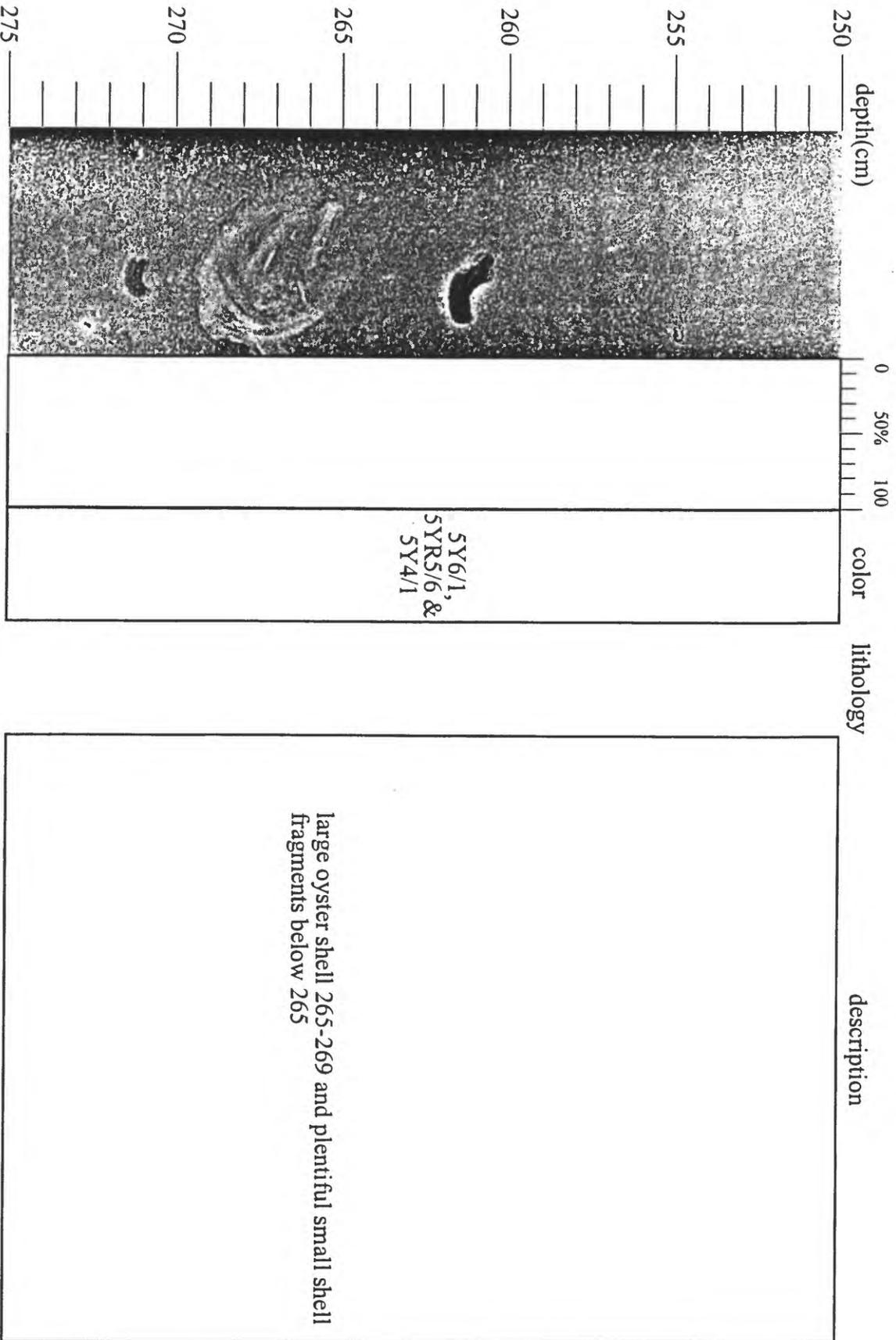
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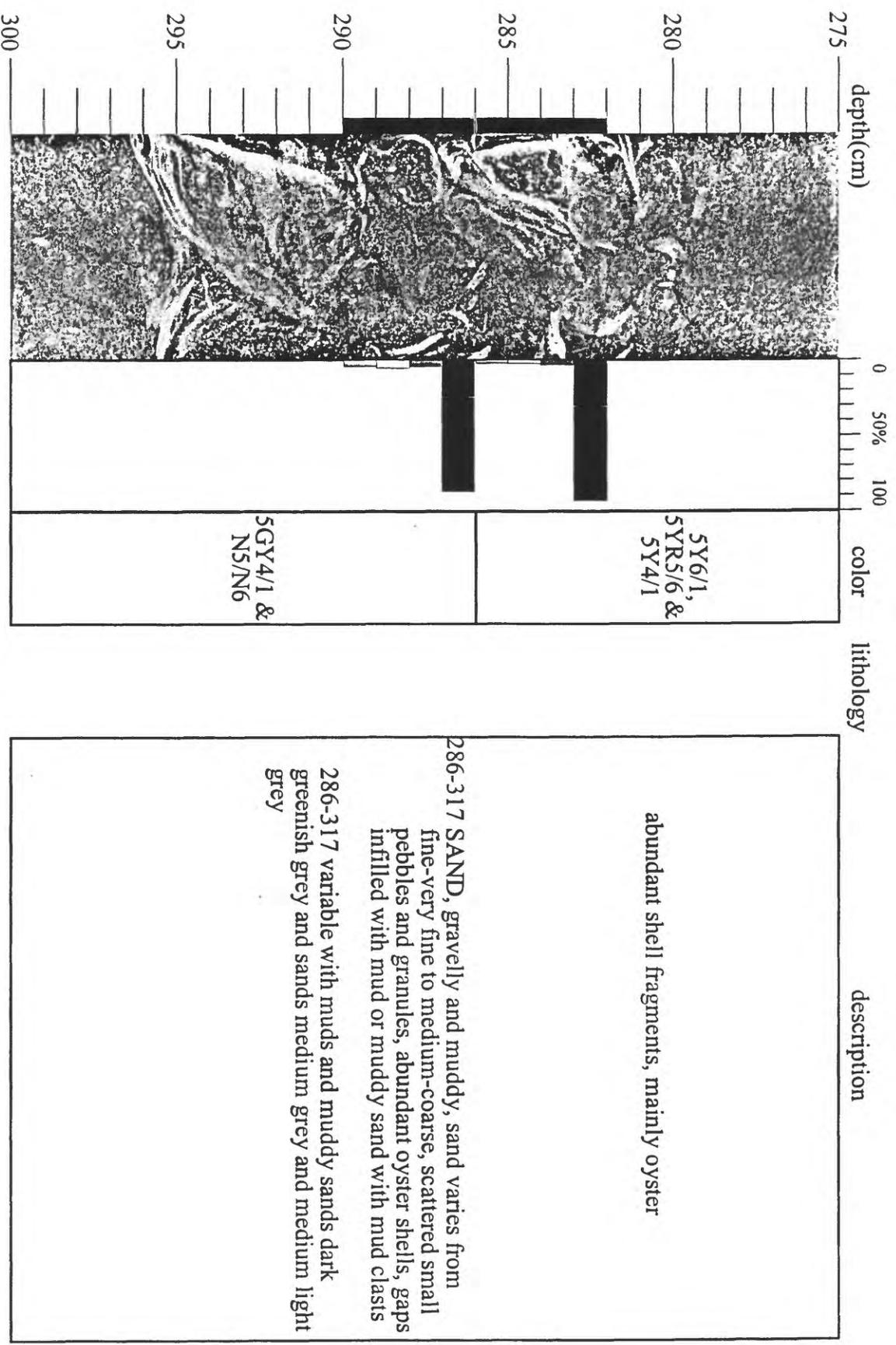
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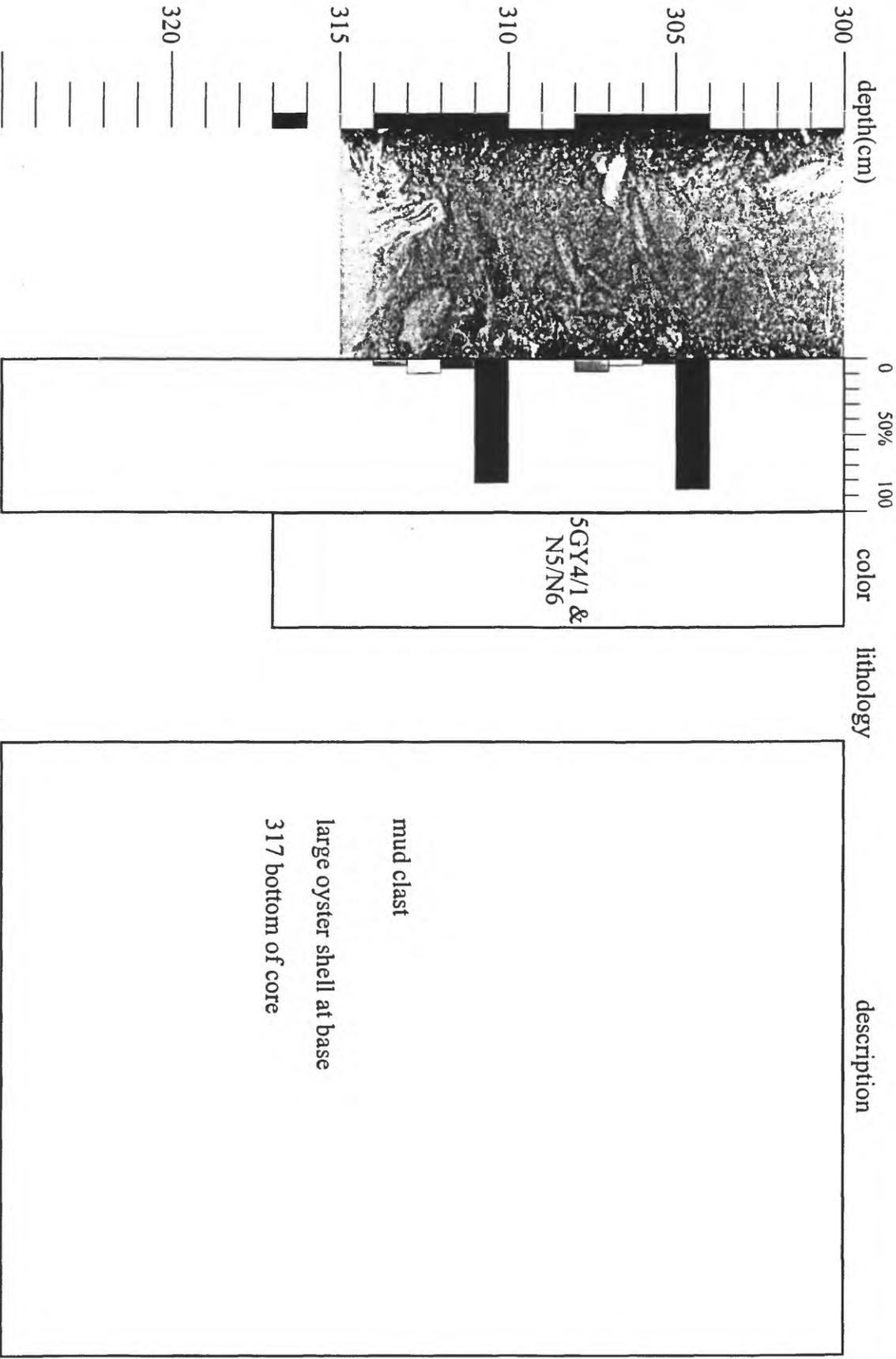
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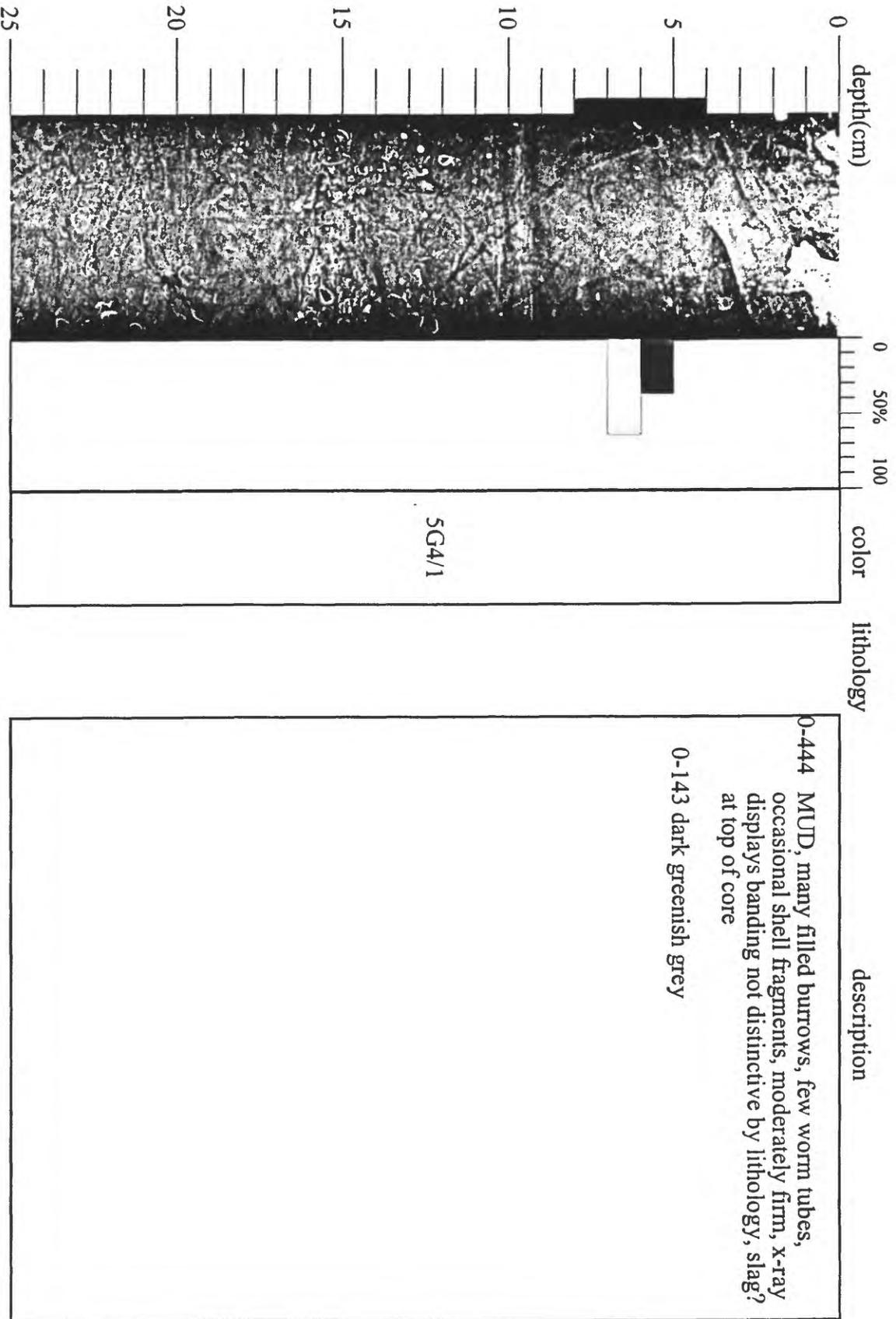
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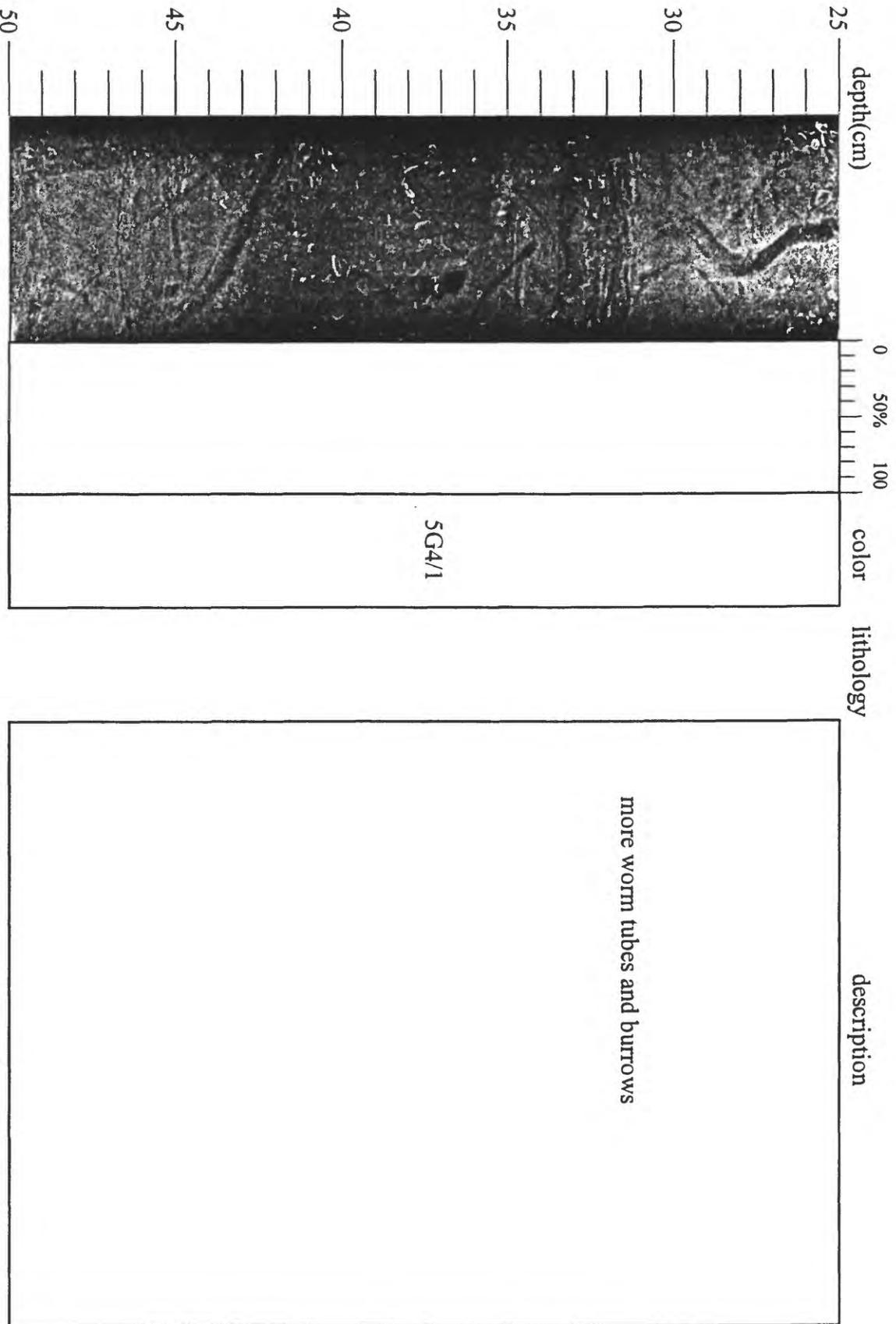
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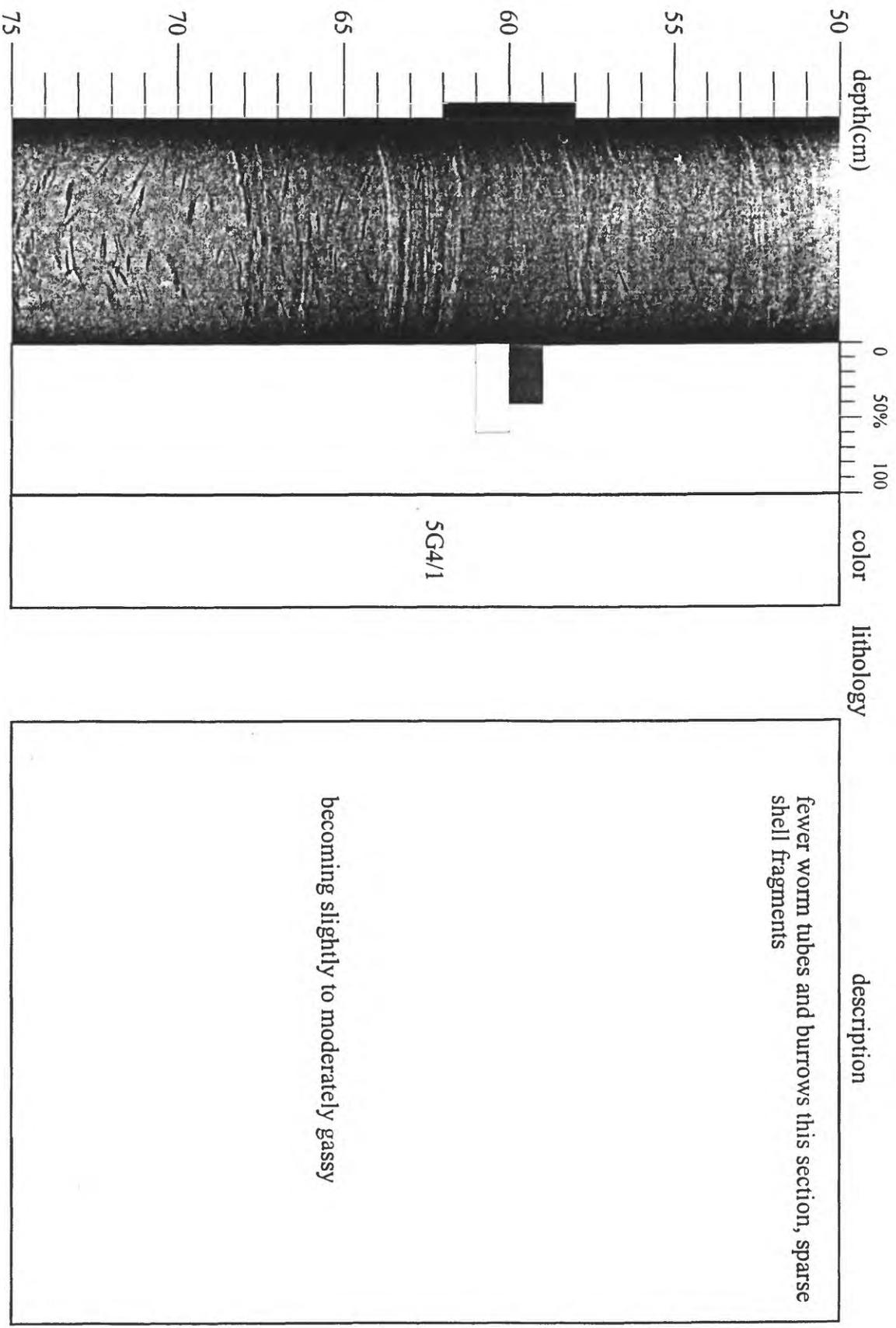
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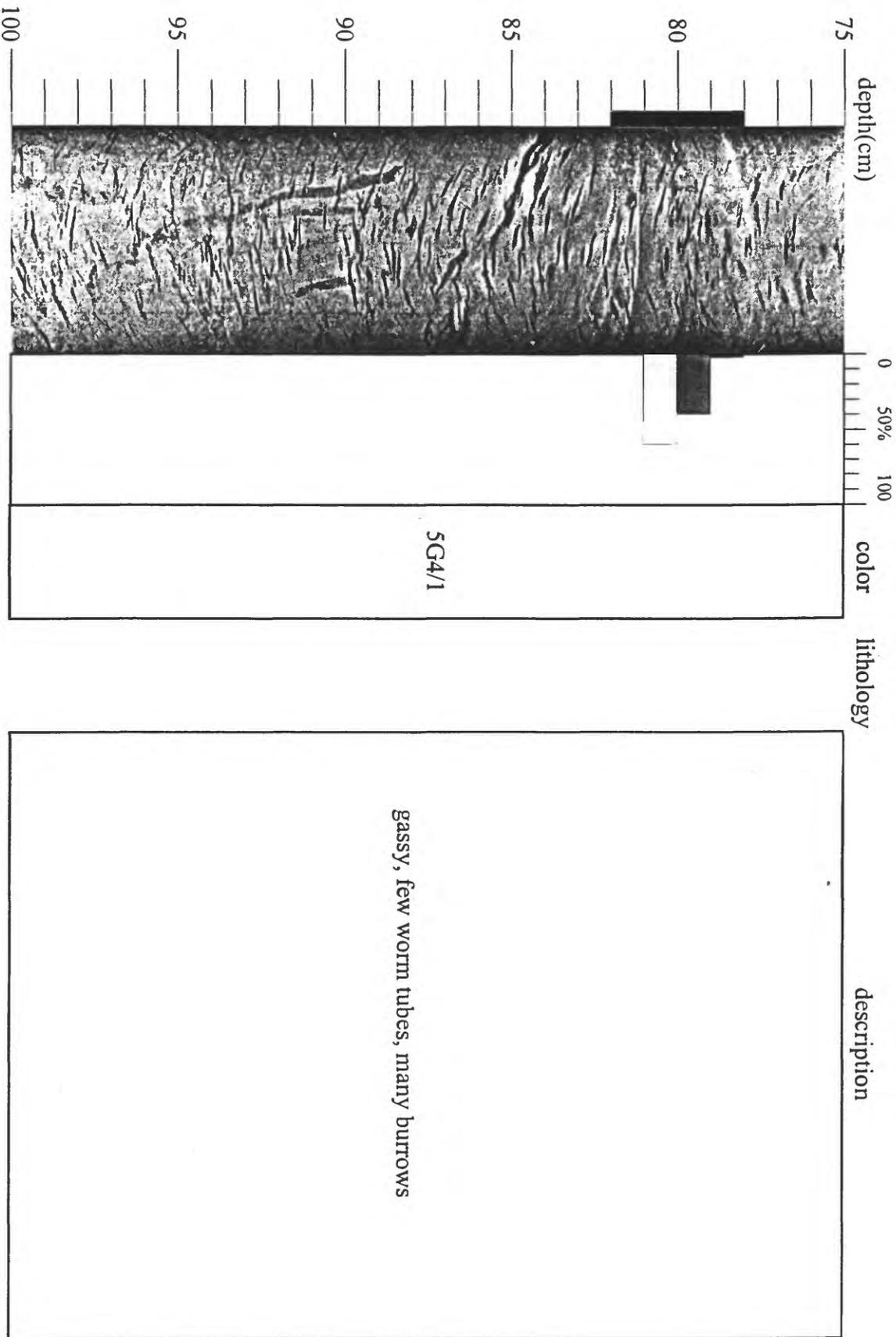
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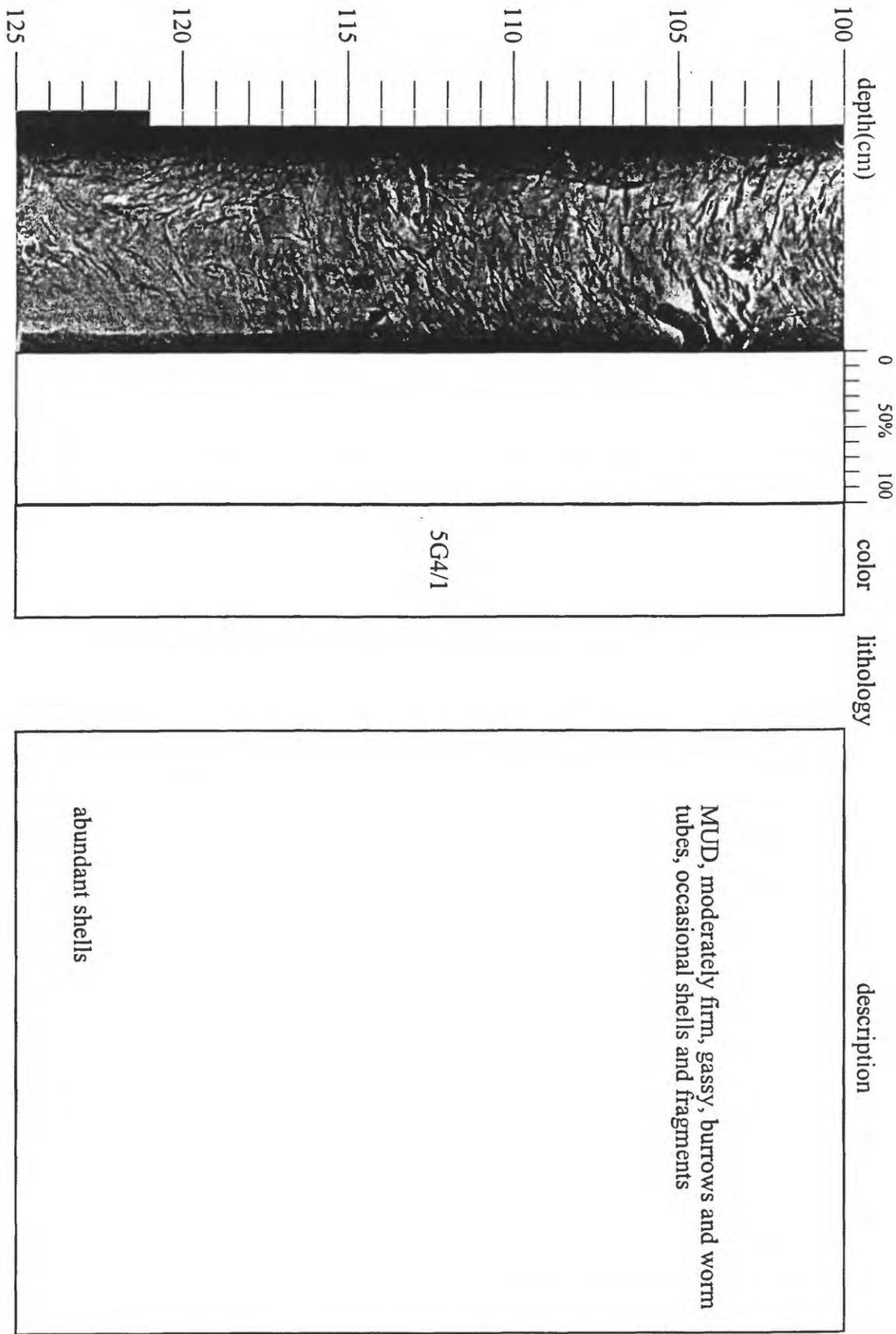
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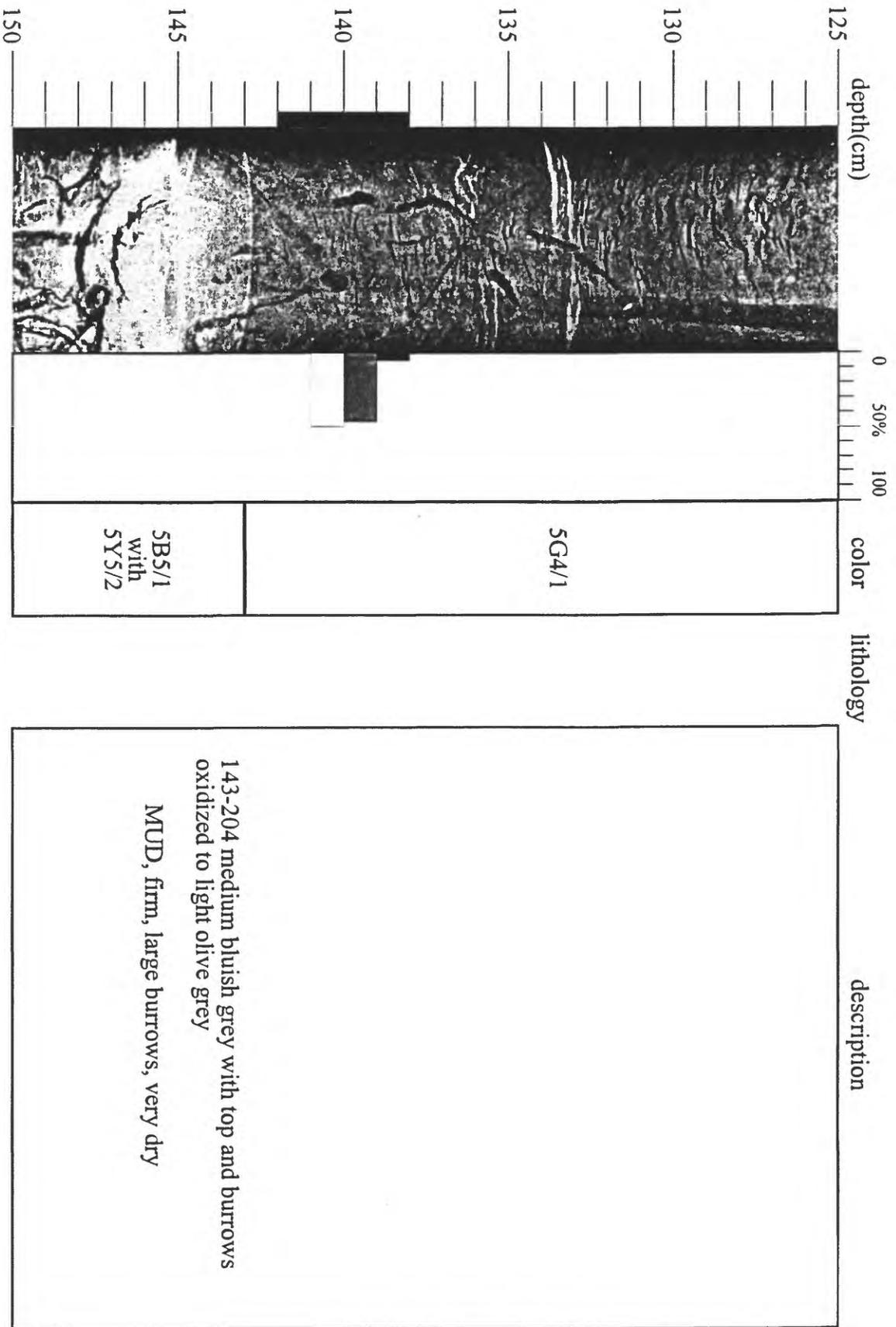
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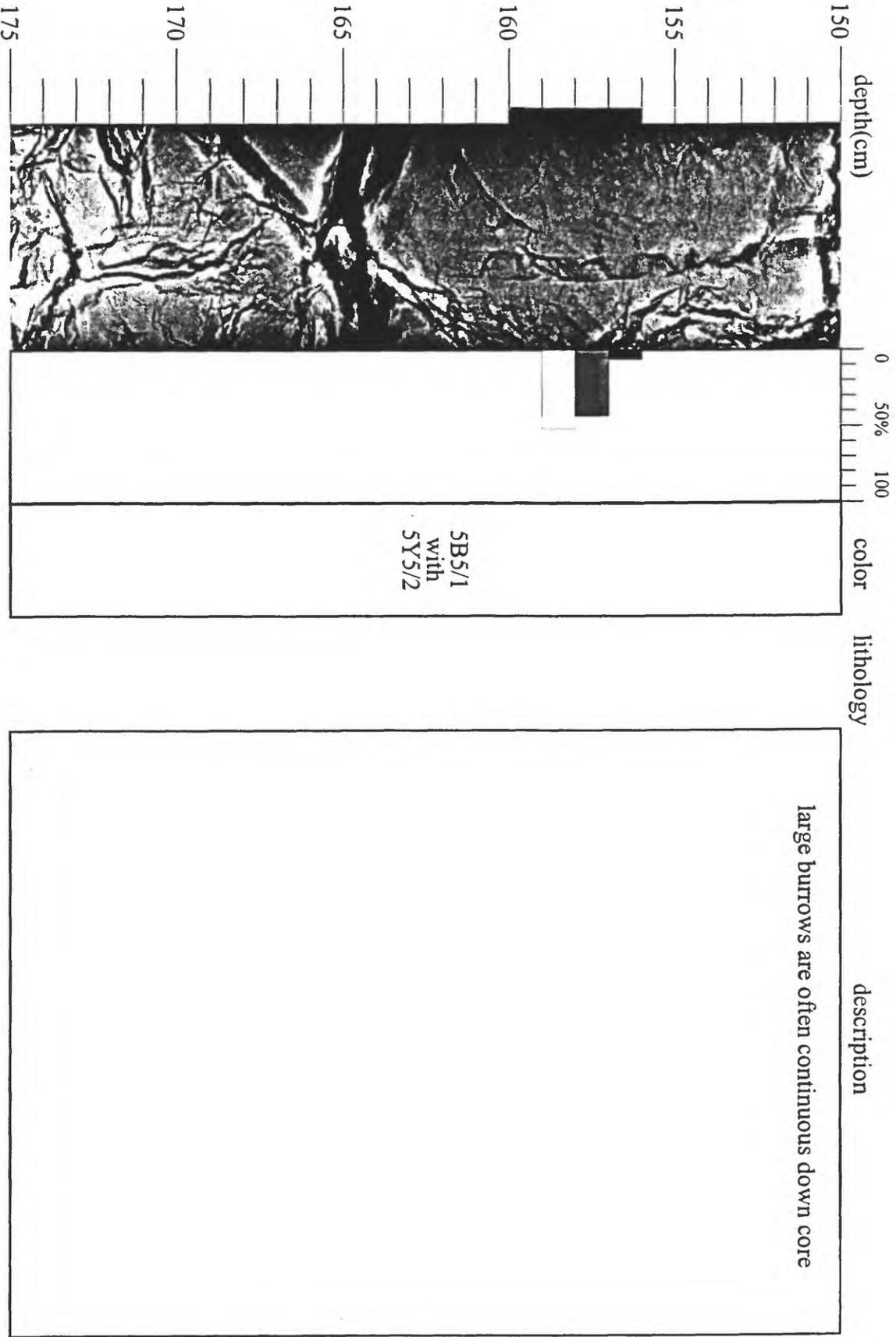
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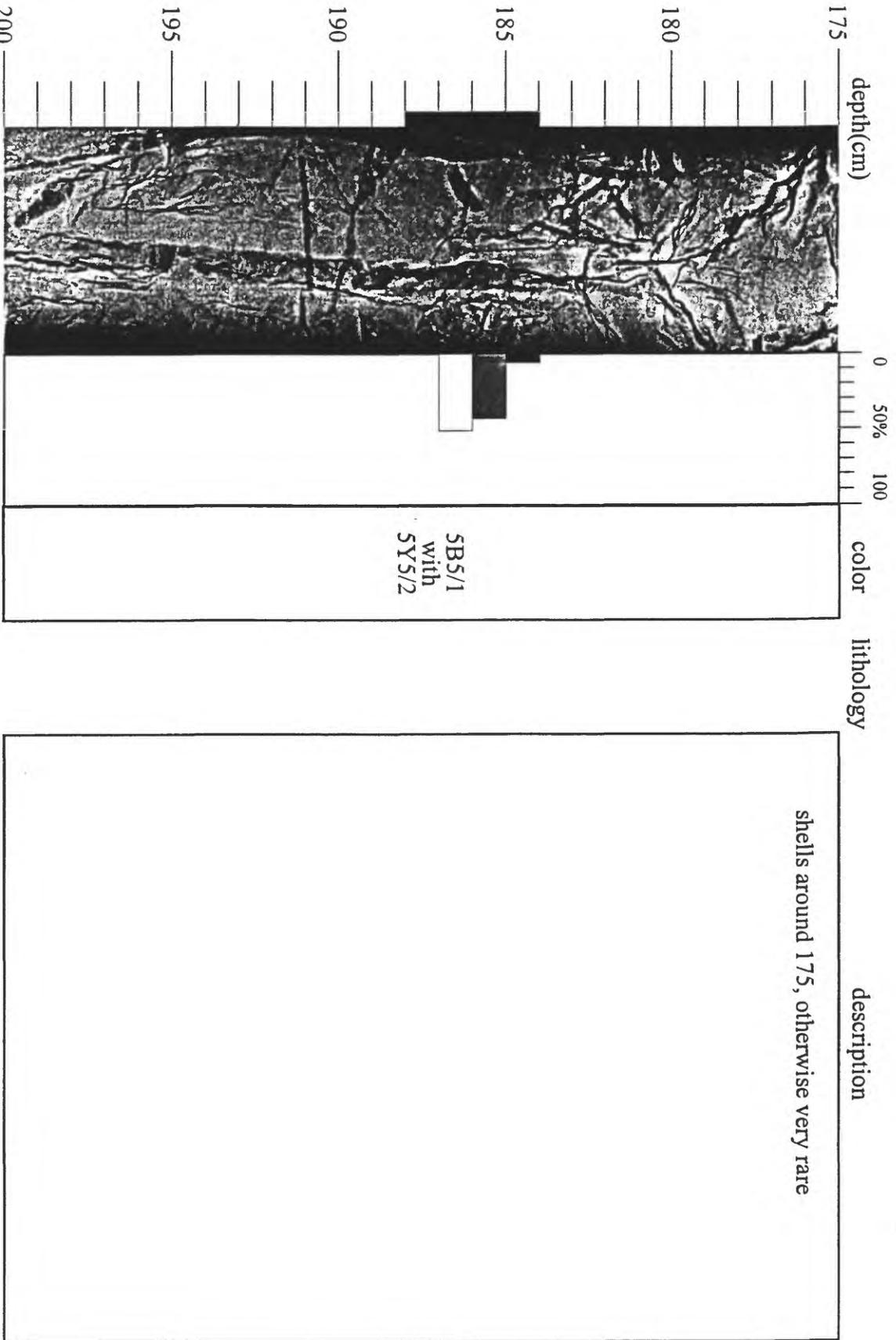
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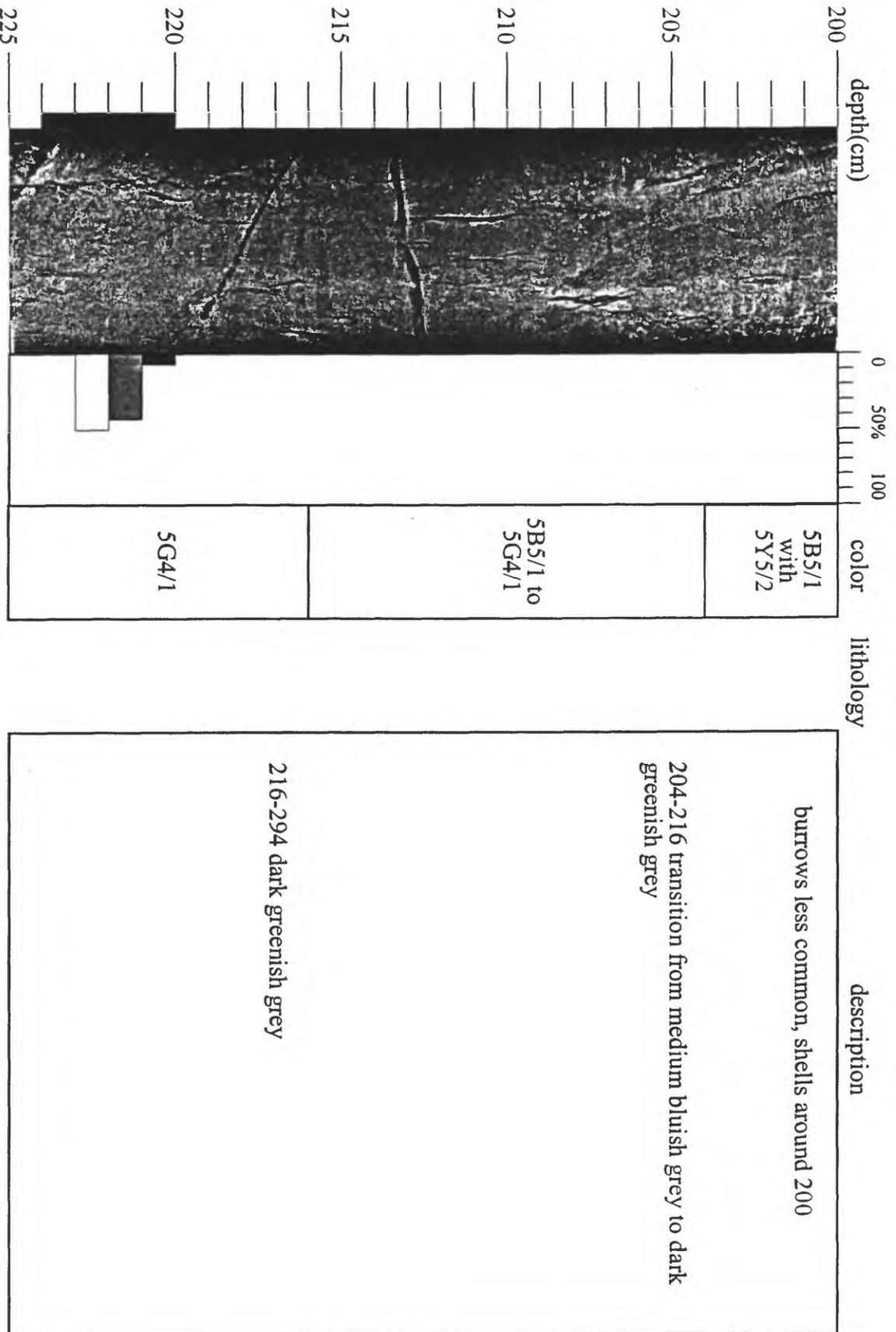
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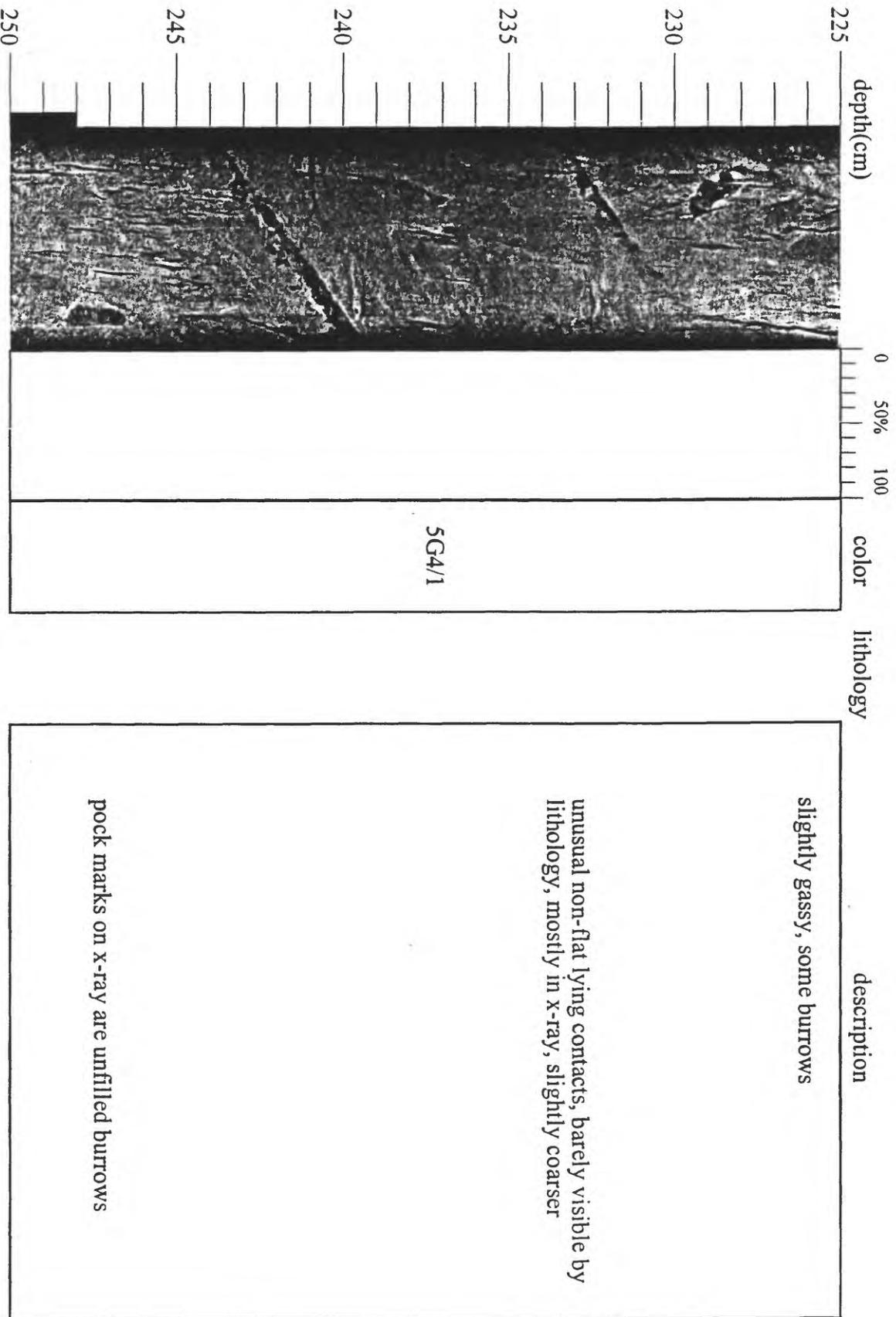
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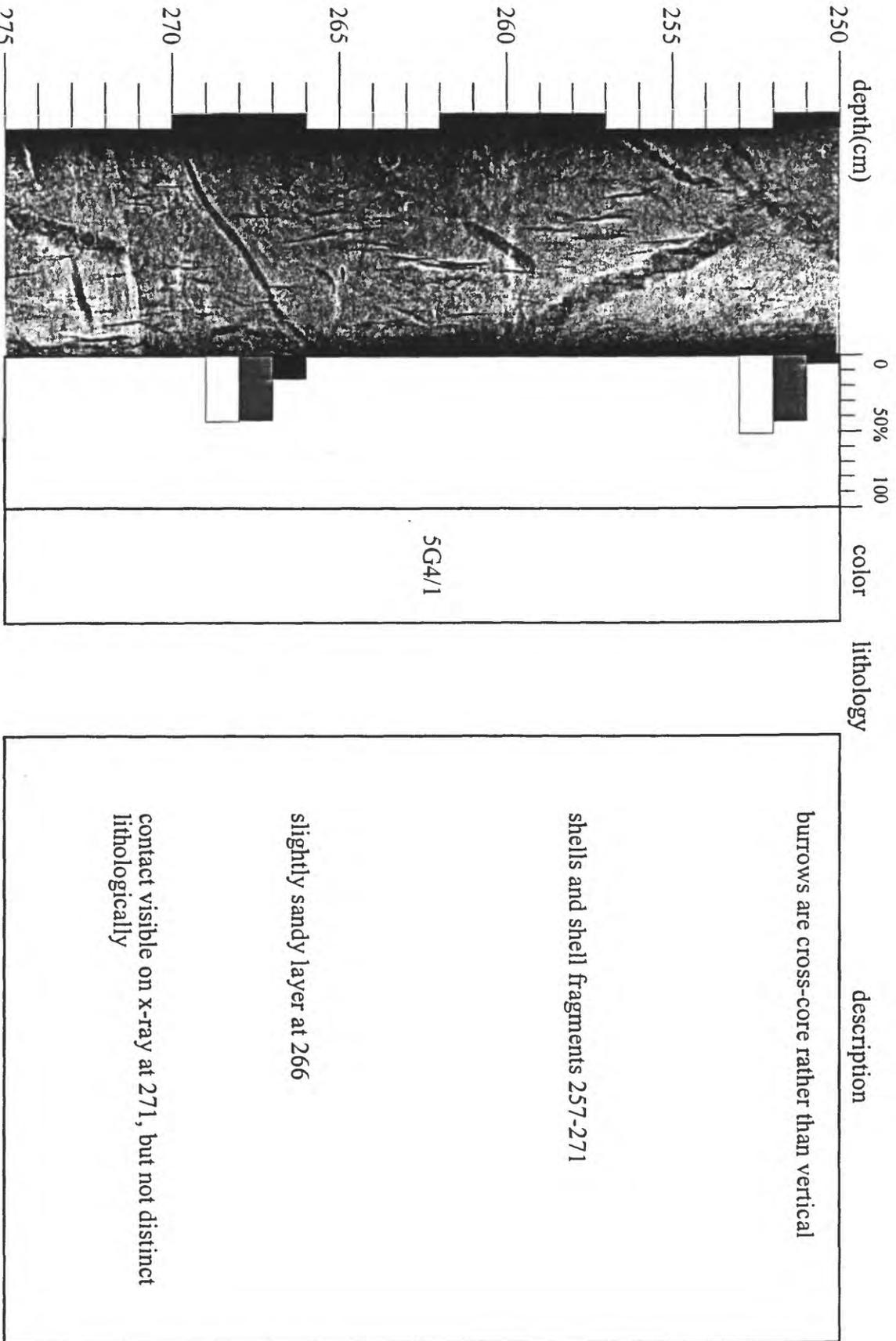
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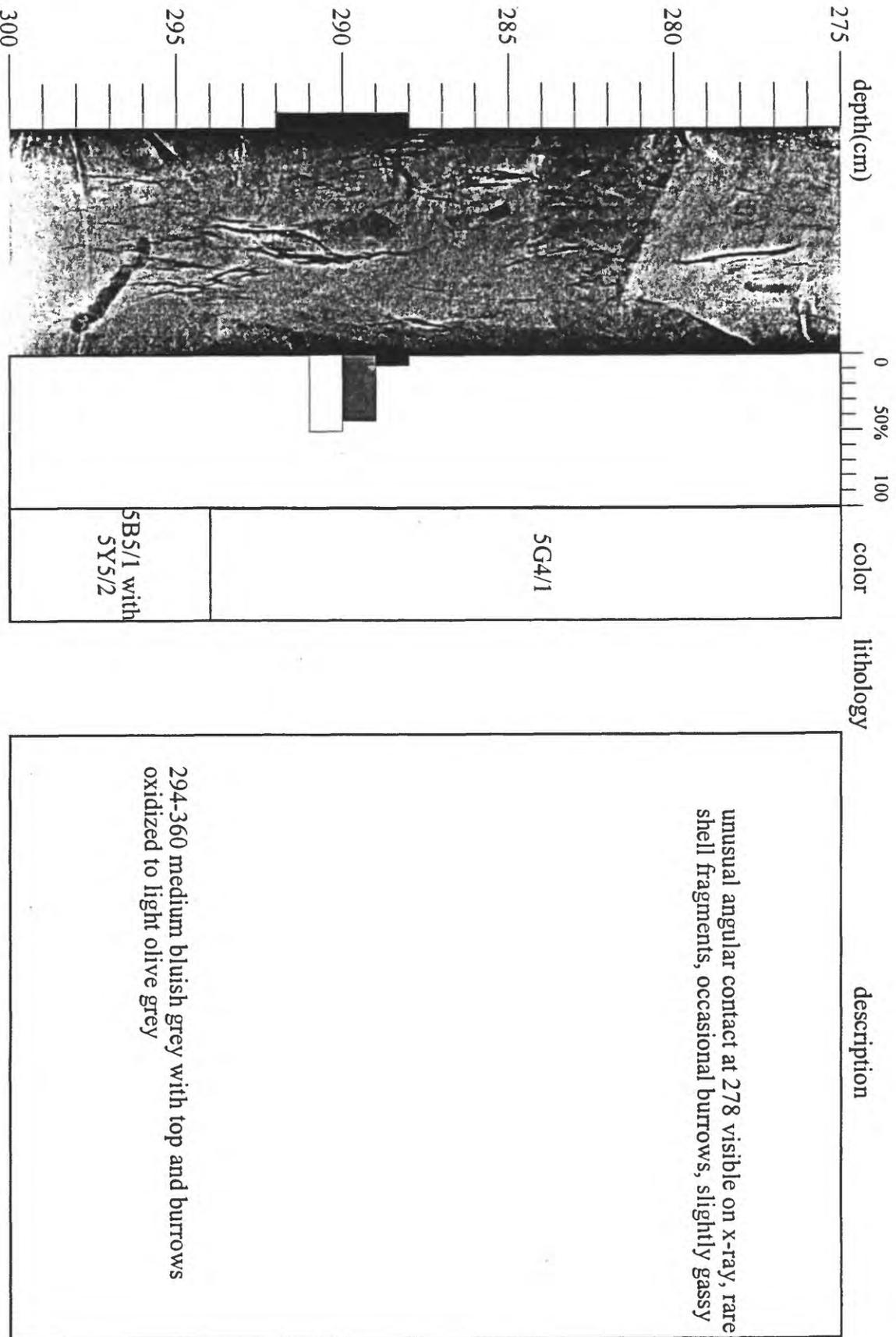
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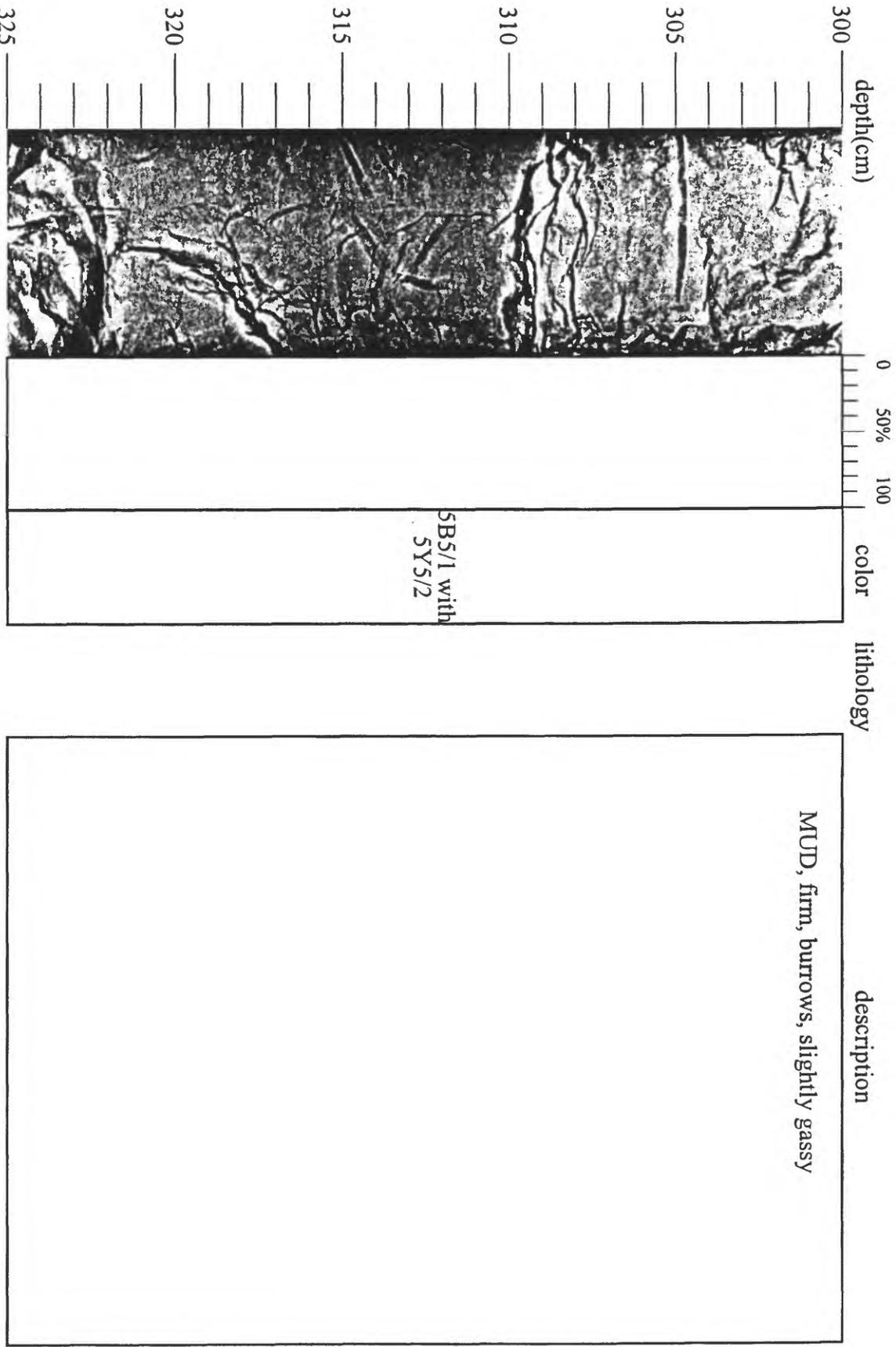
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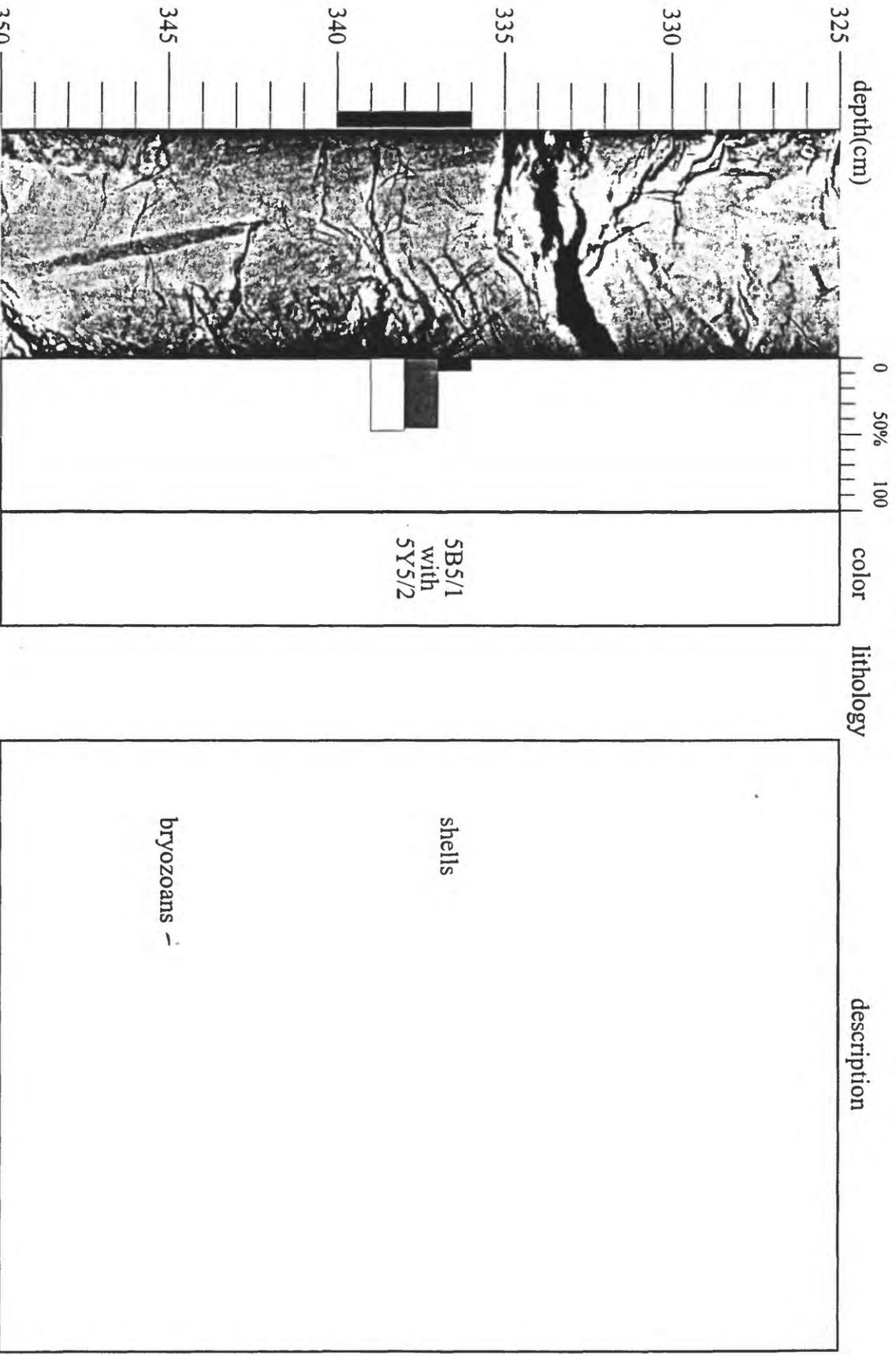
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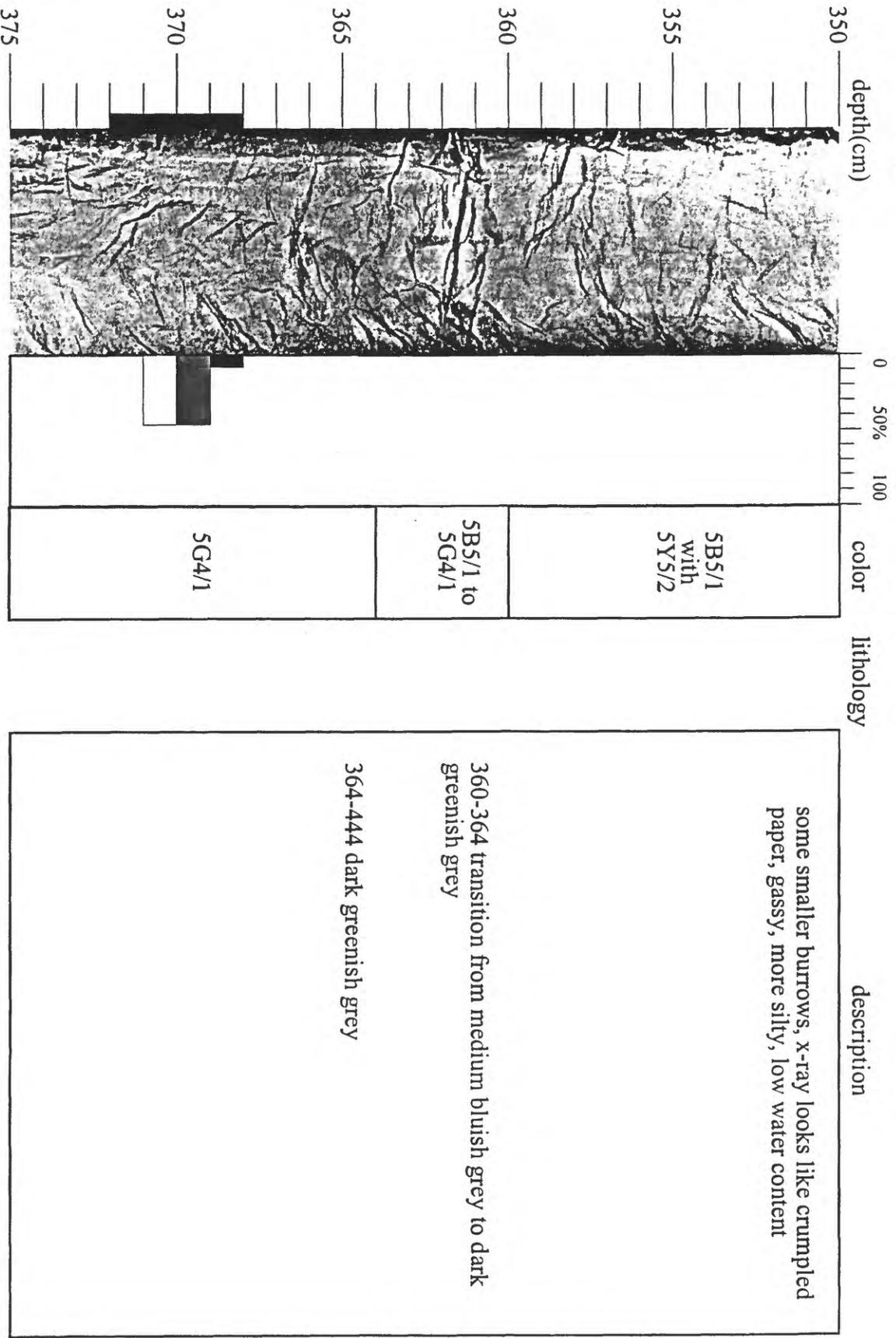
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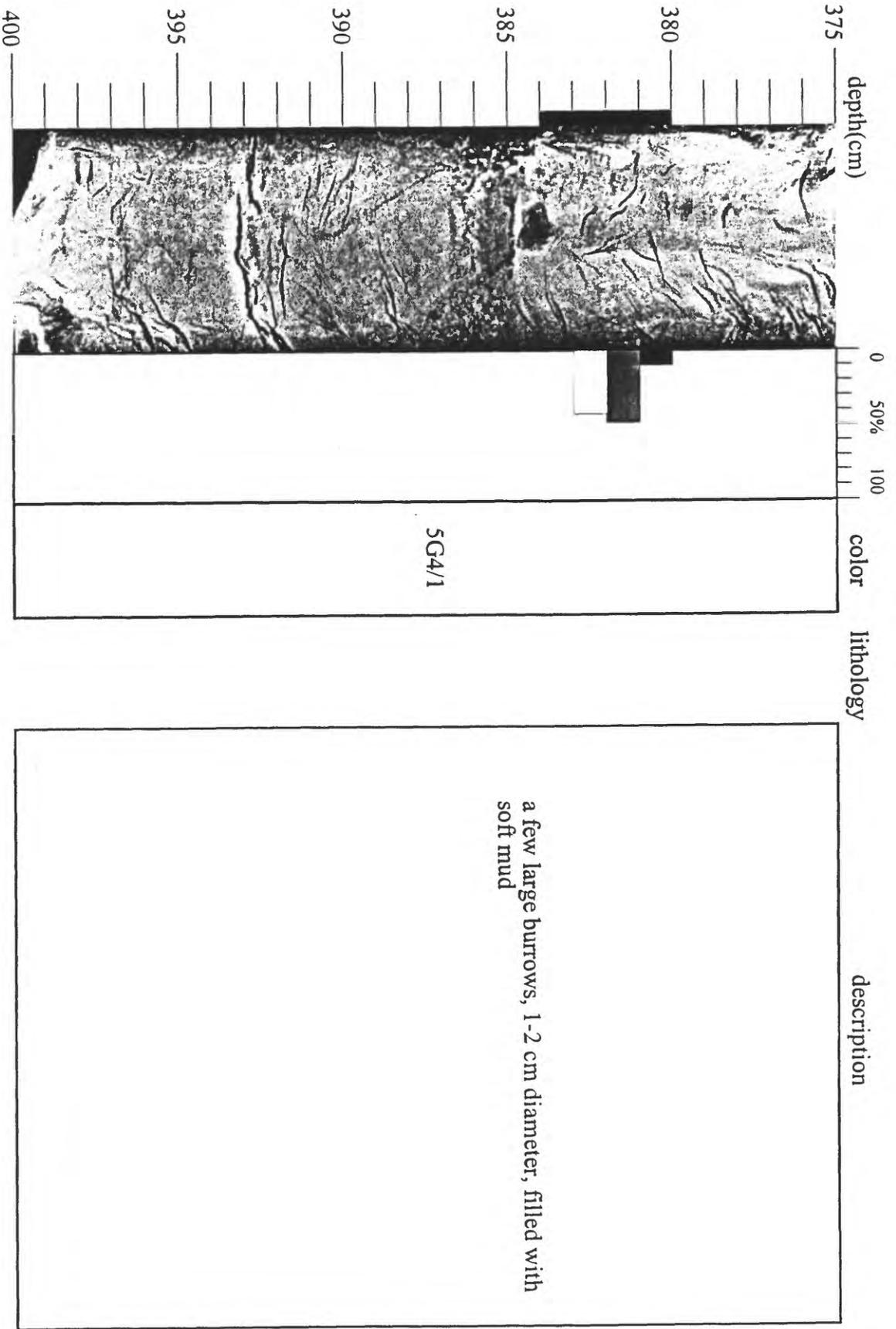


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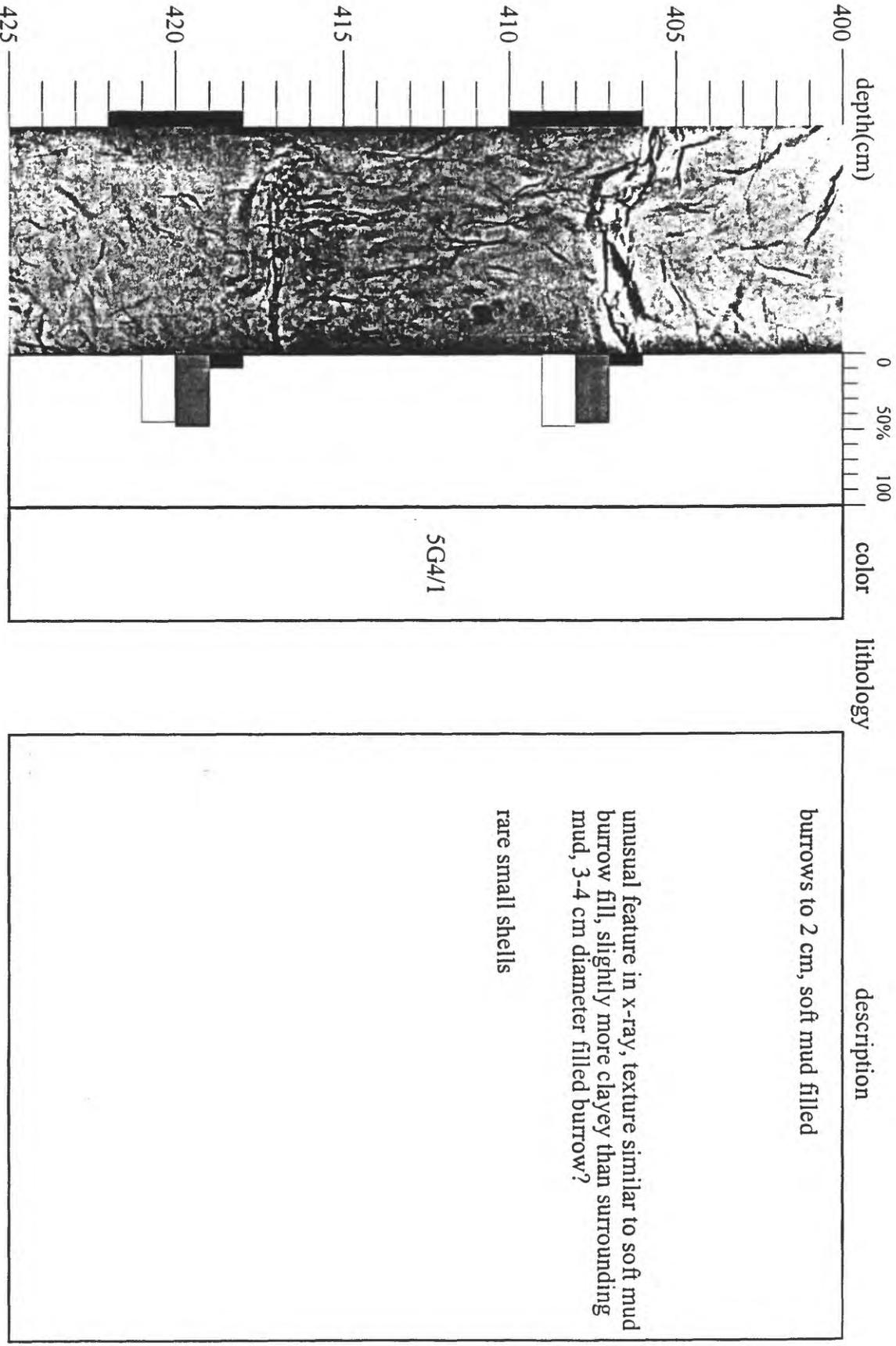


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Core PRCK 3-2



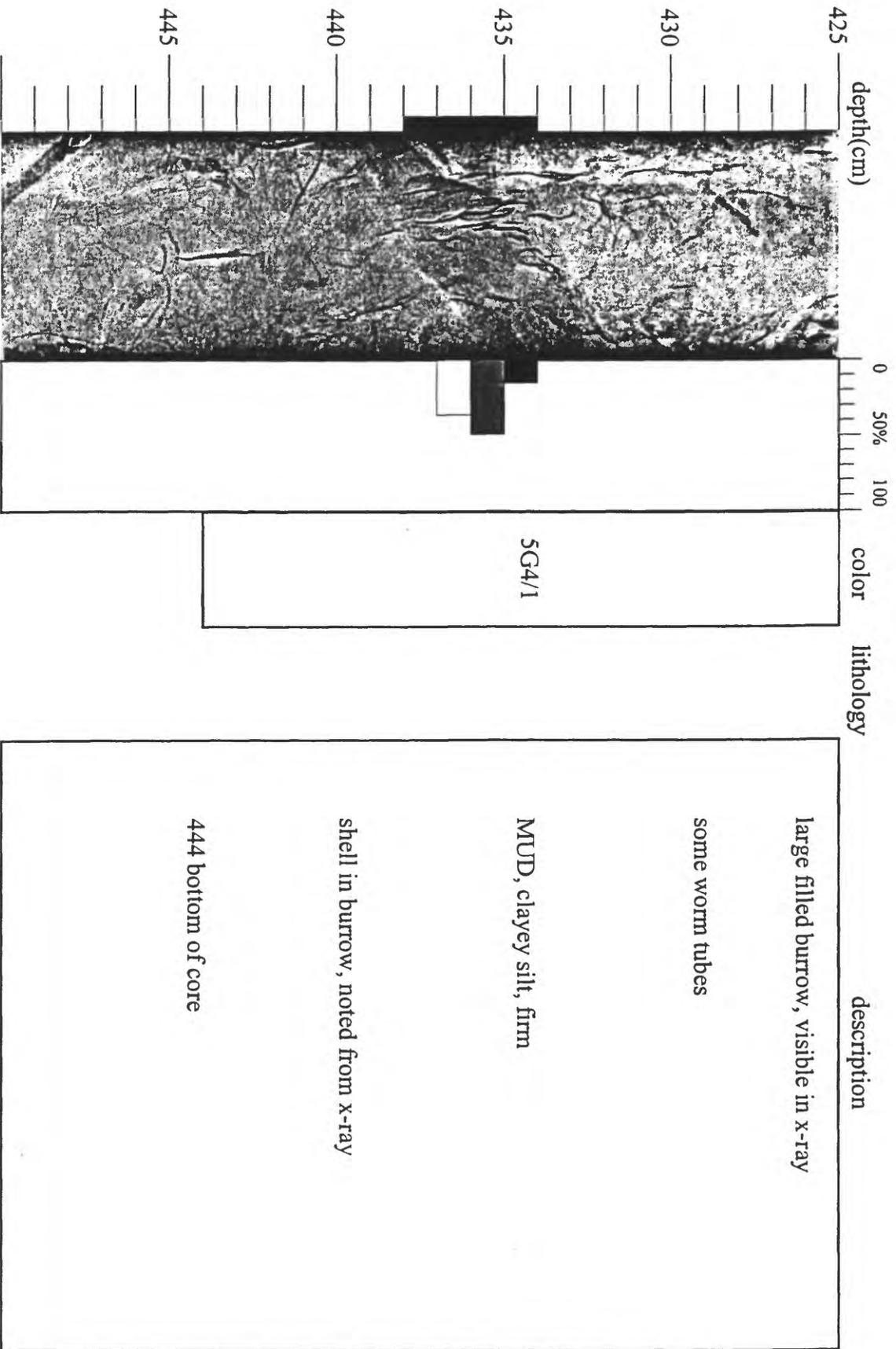
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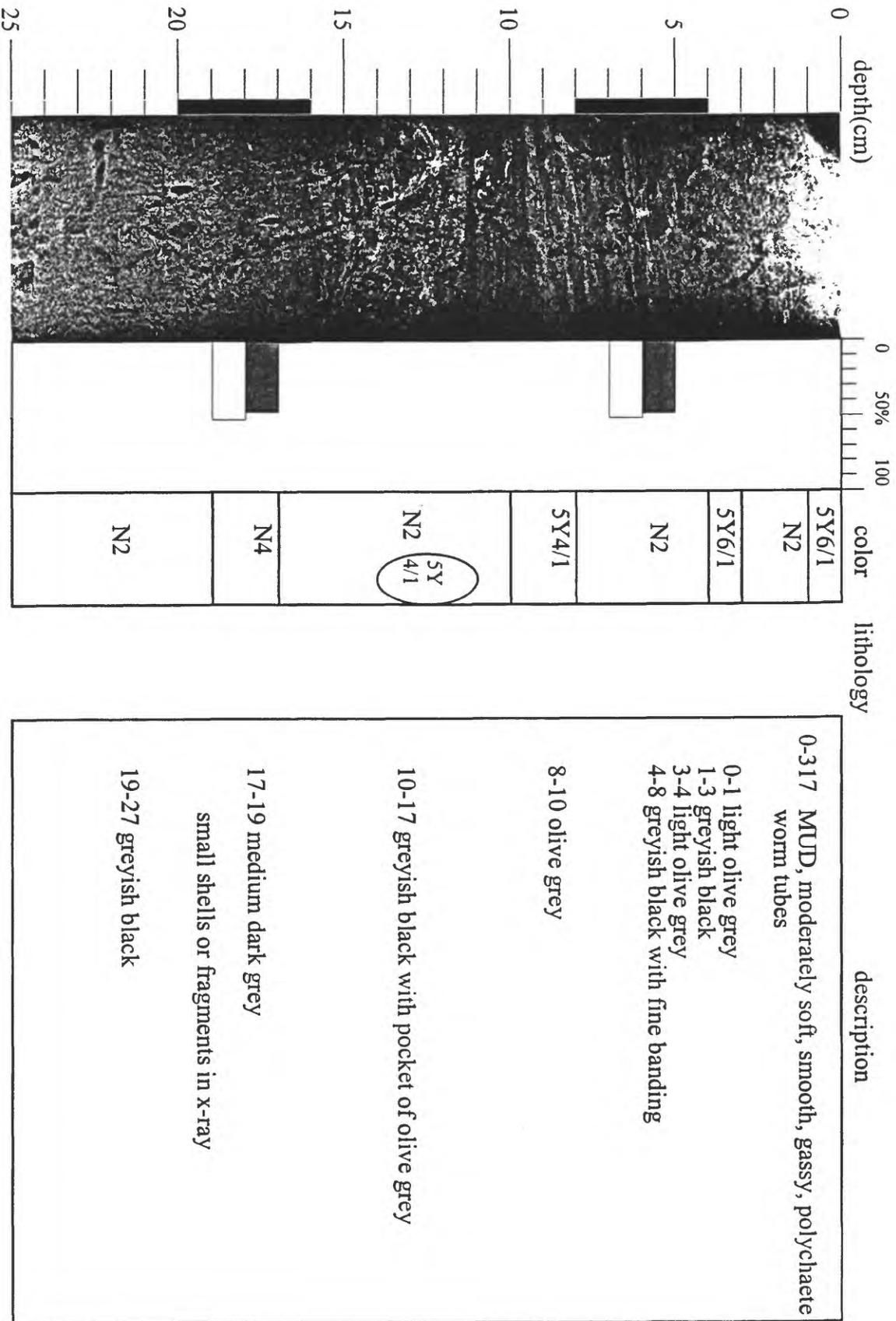
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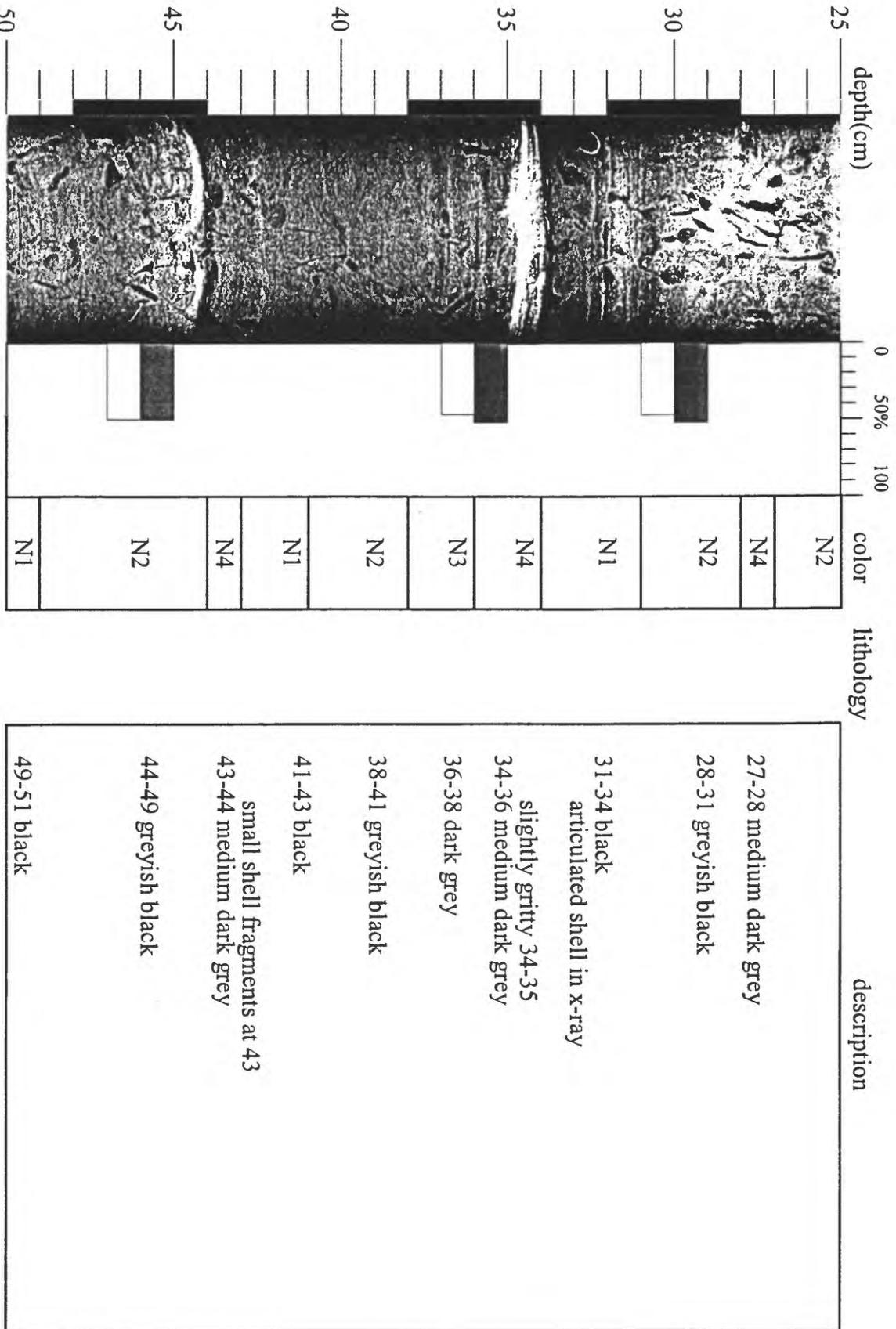
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Core LCPTK 1-1



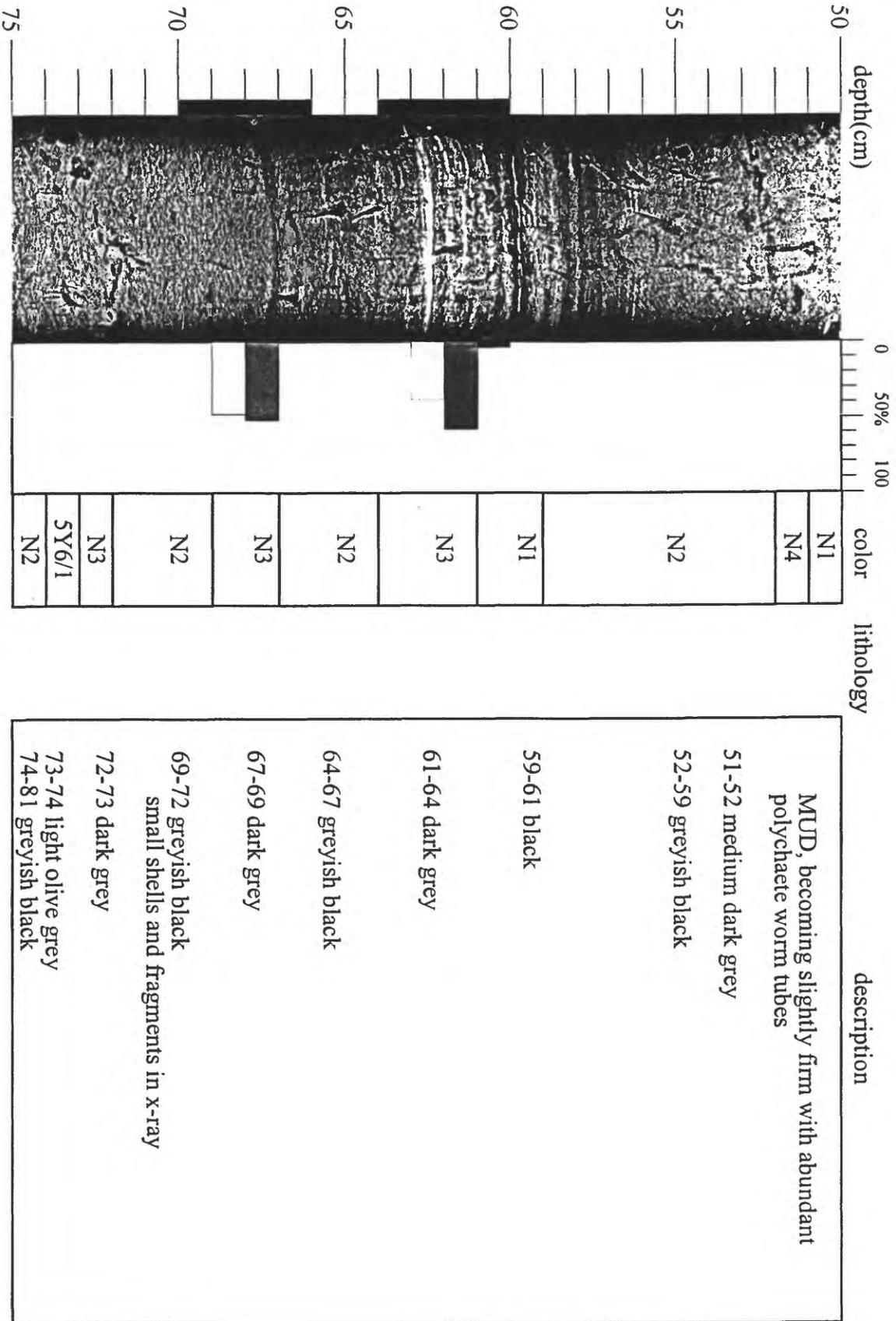
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Core LCP TK 1-1



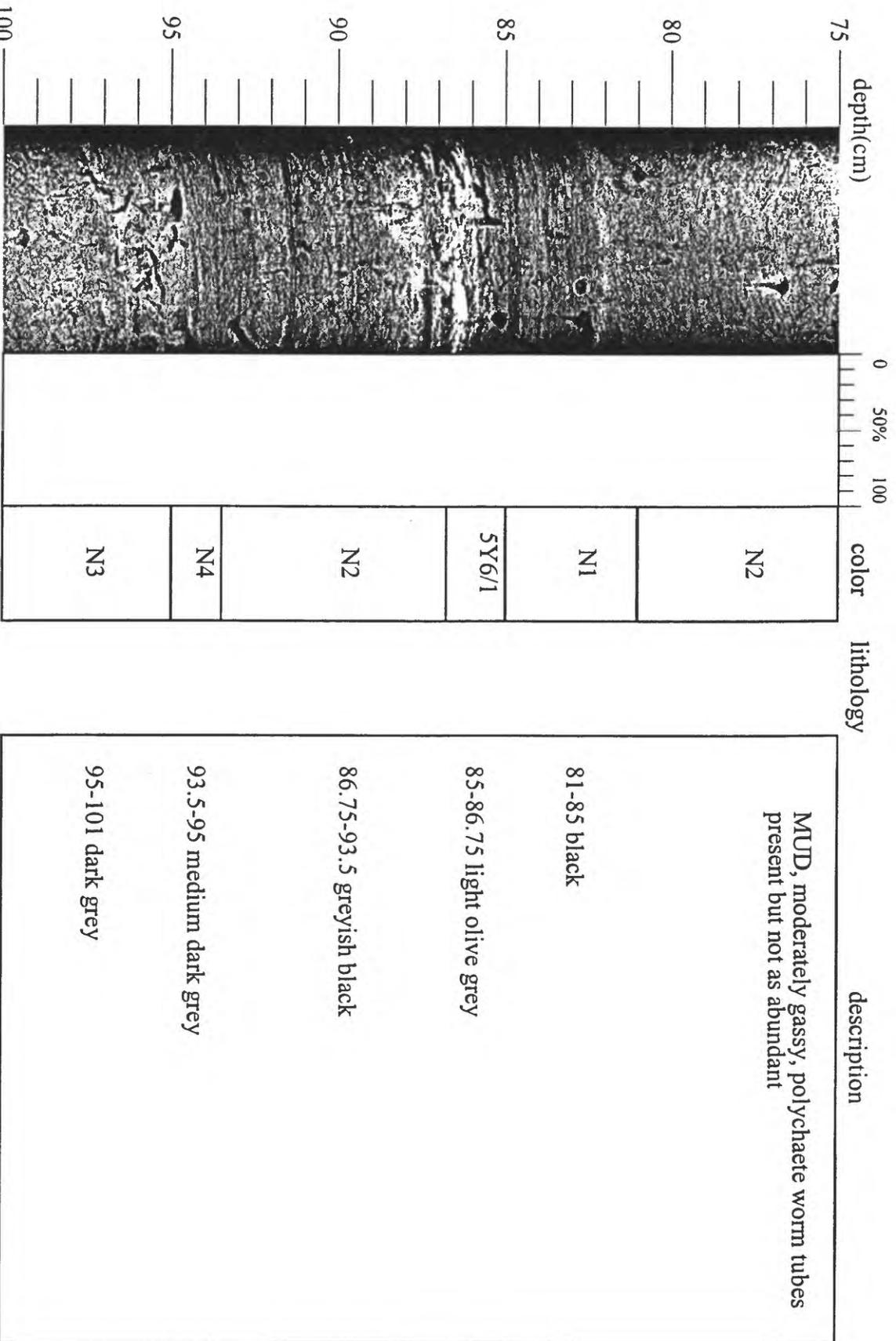
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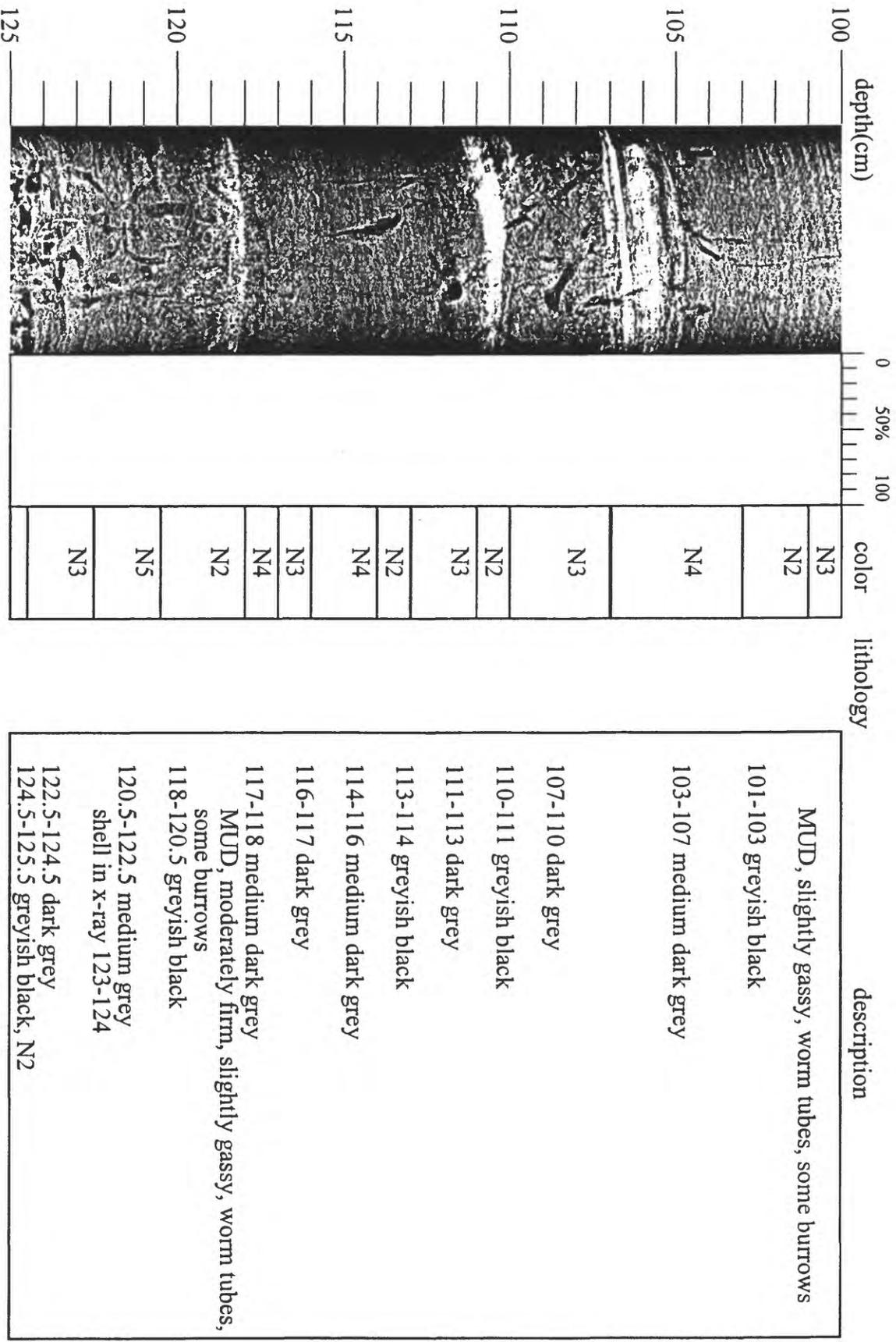
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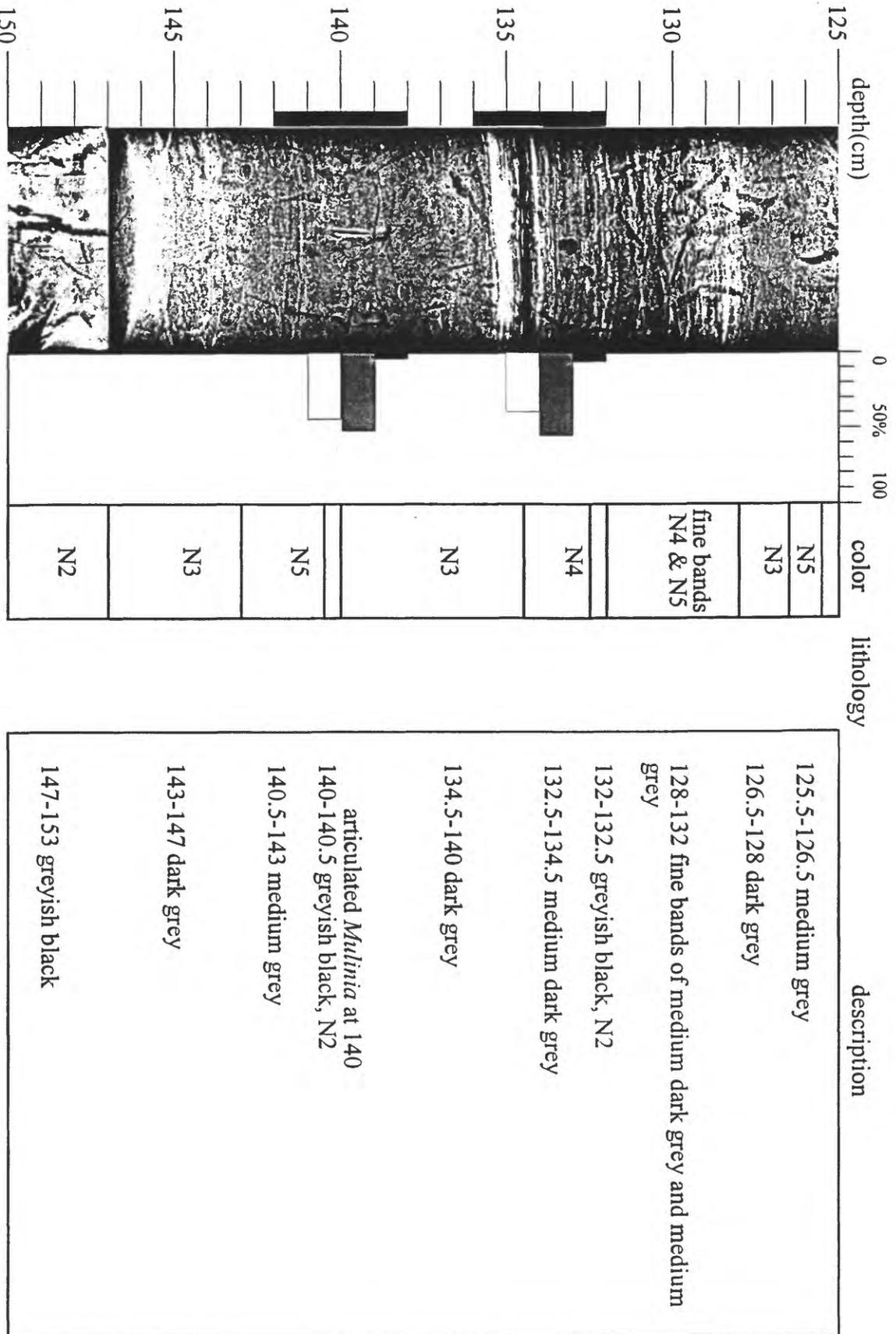
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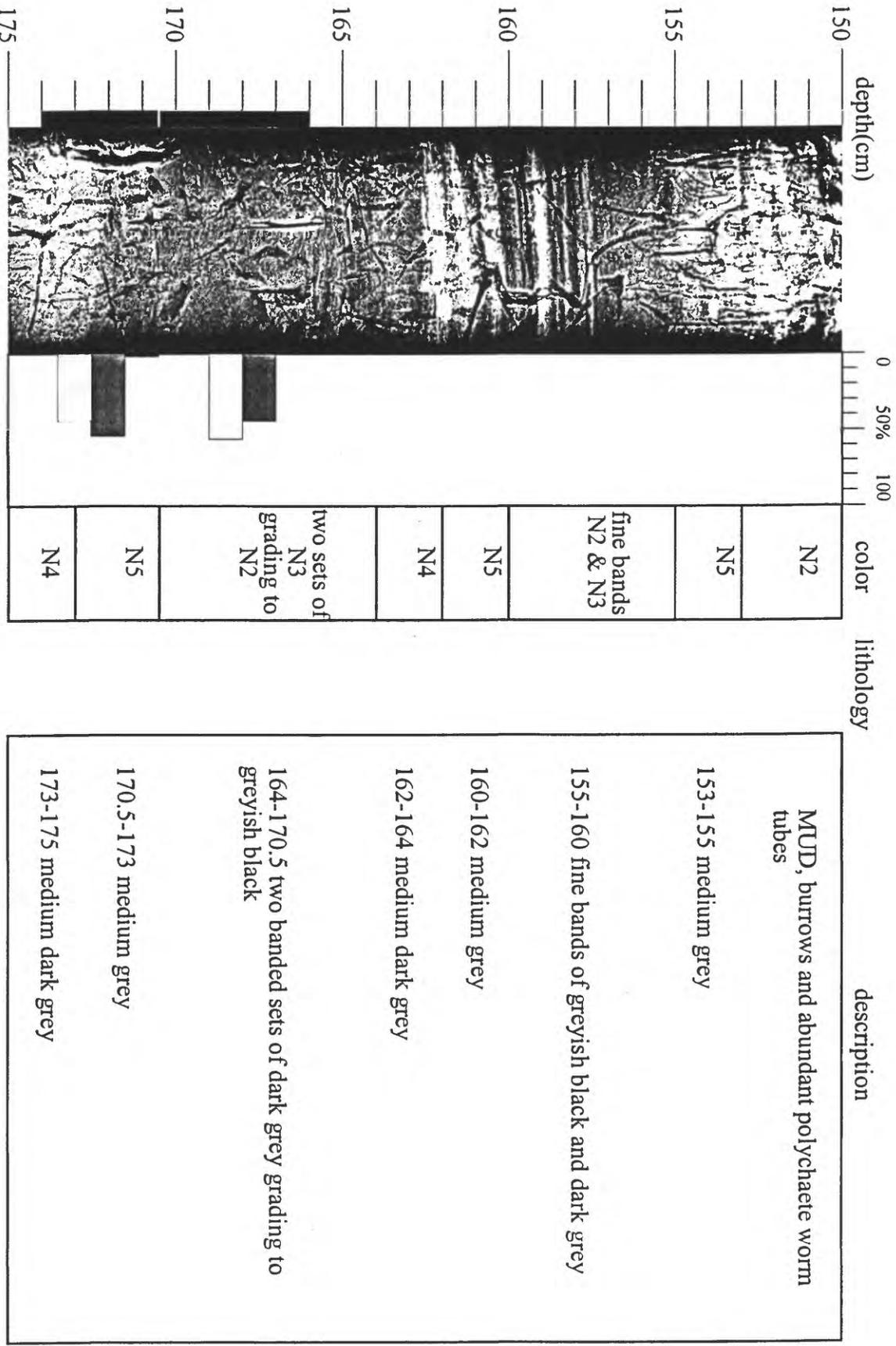
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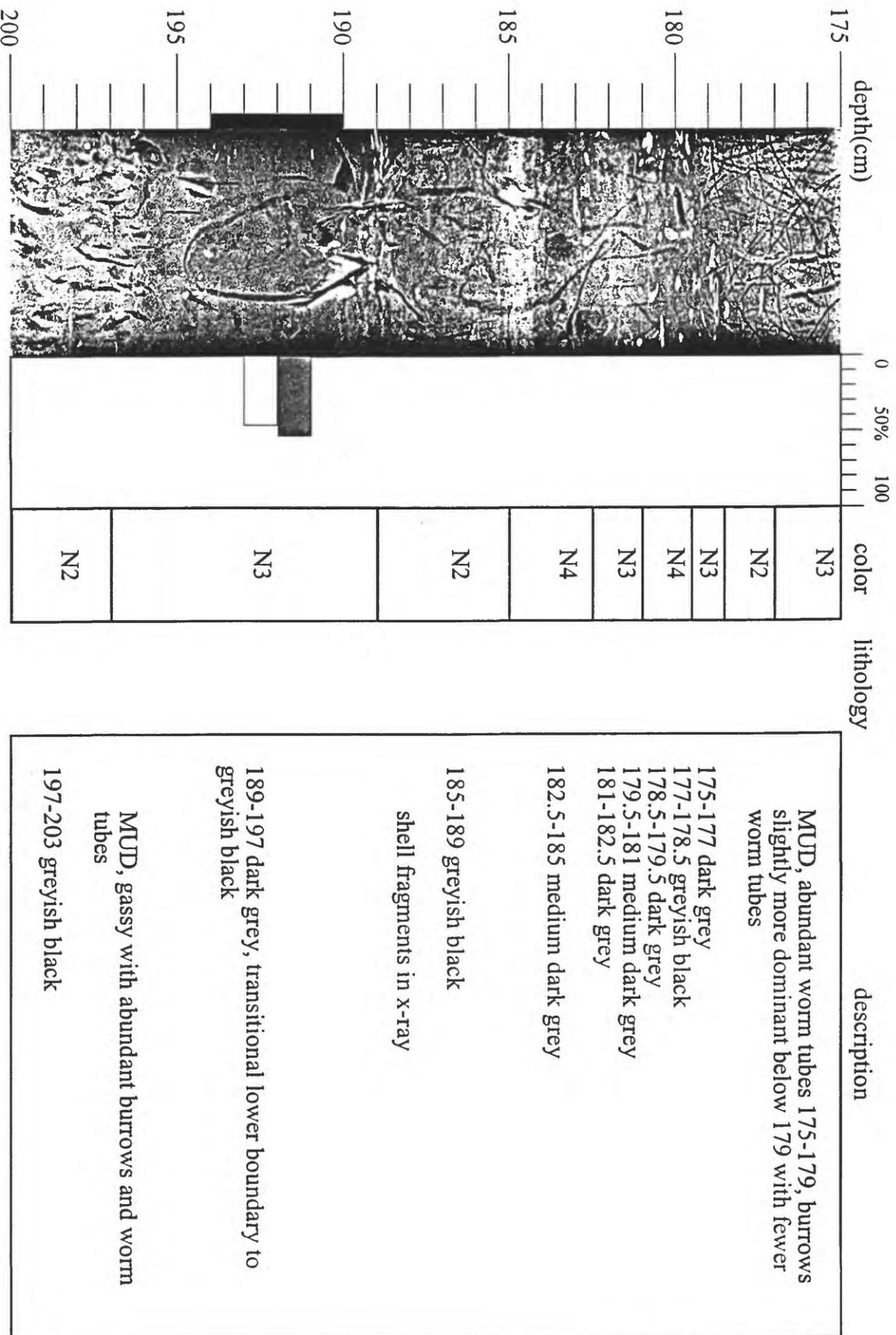
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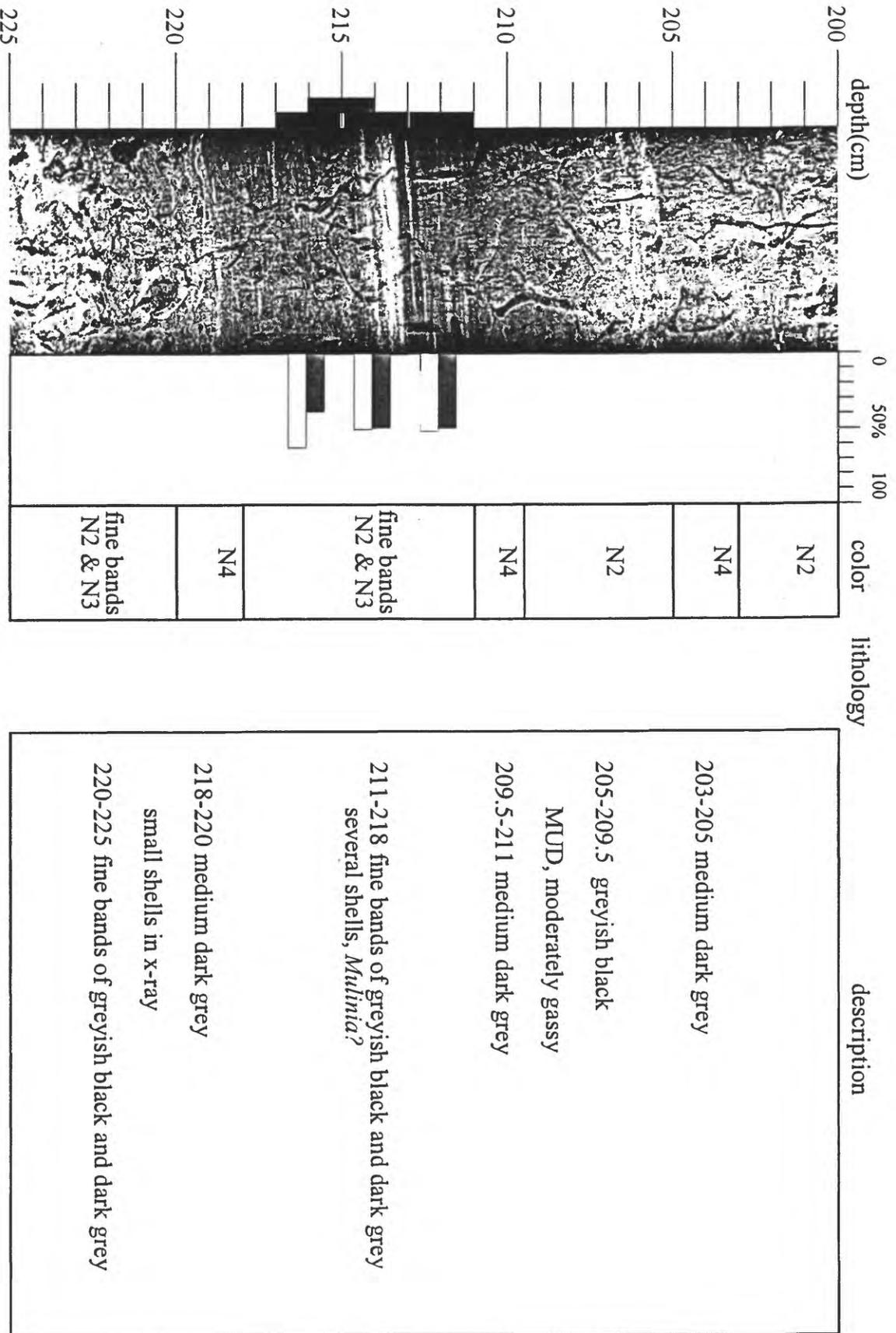
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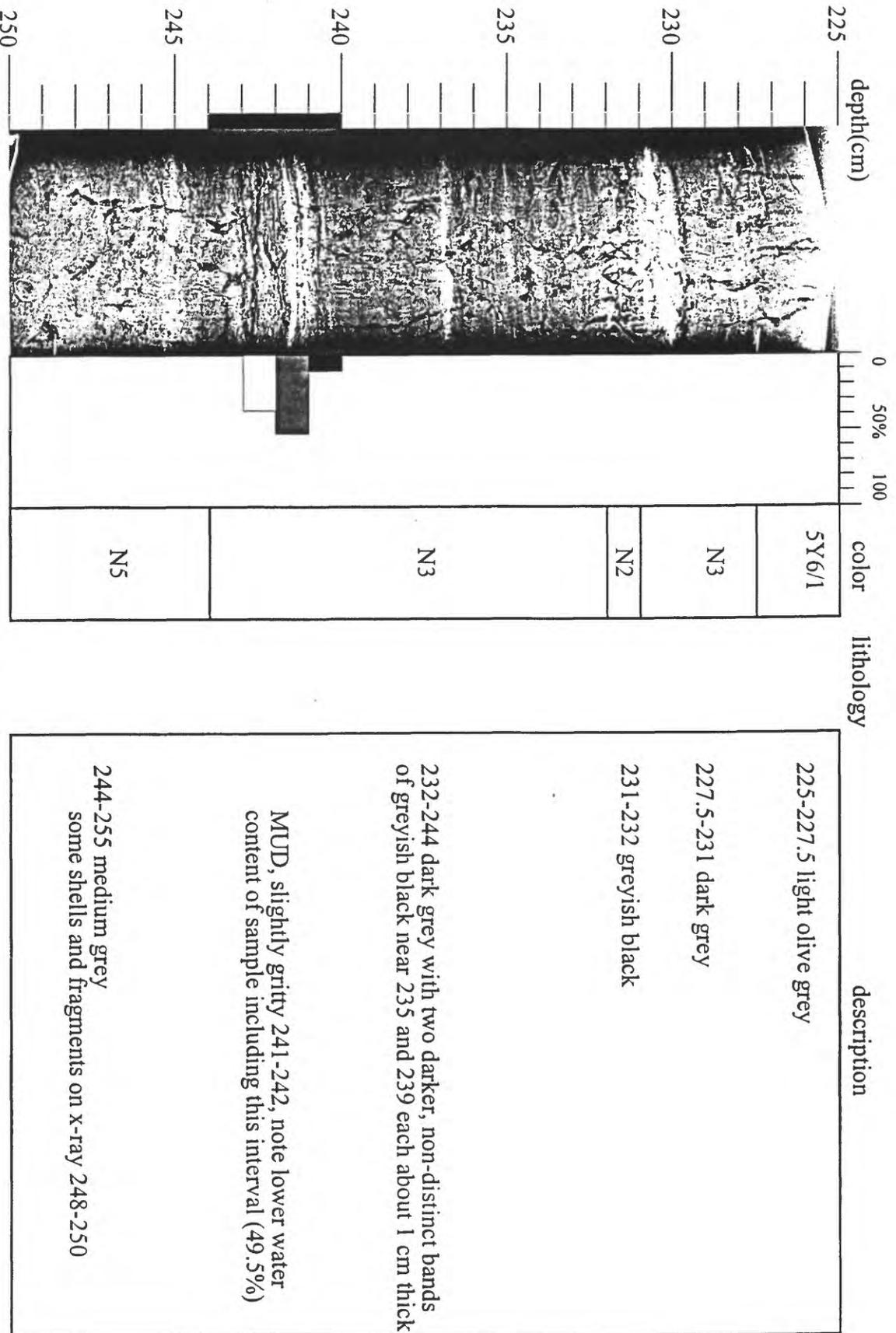
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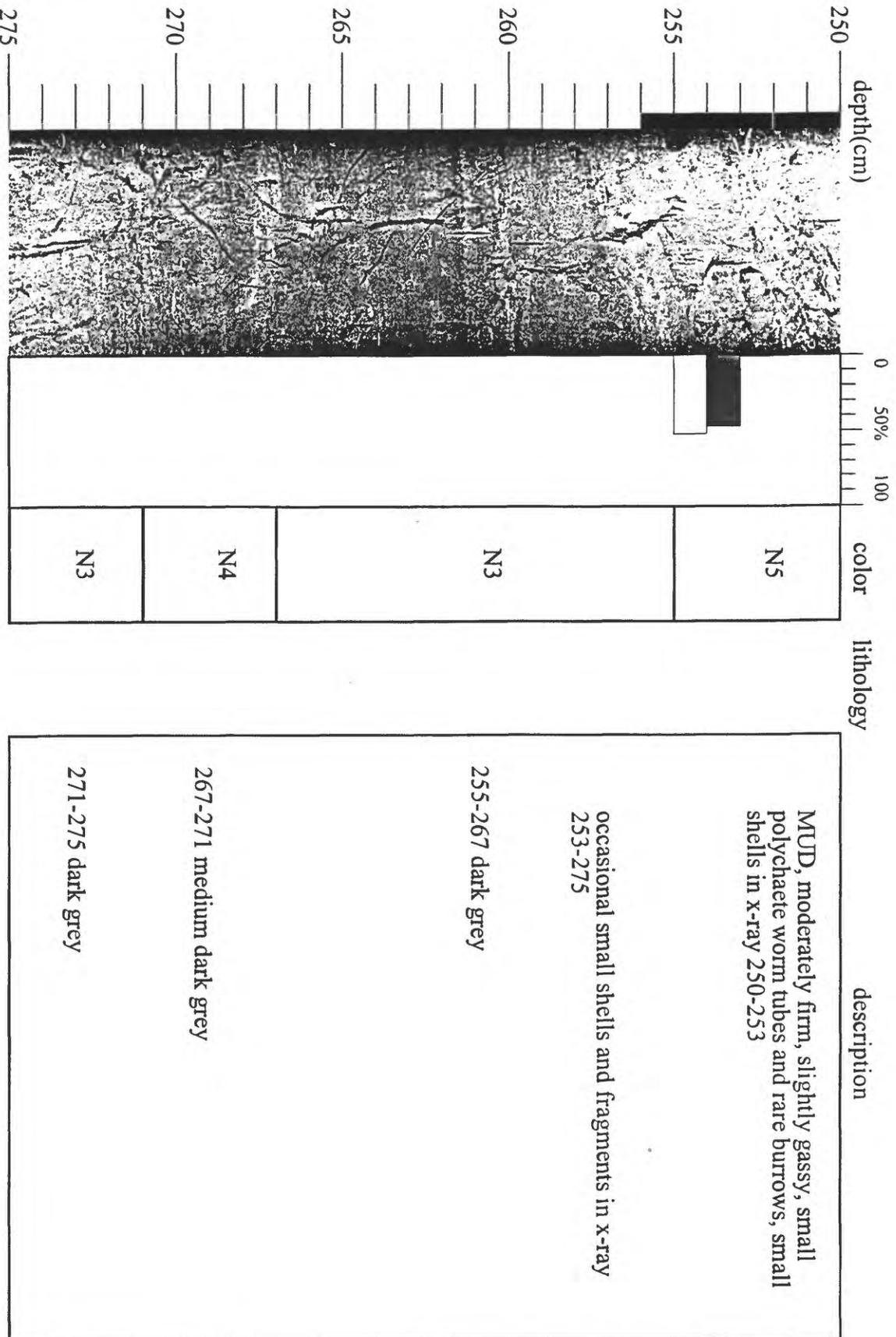
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Core LCPTK 1-1



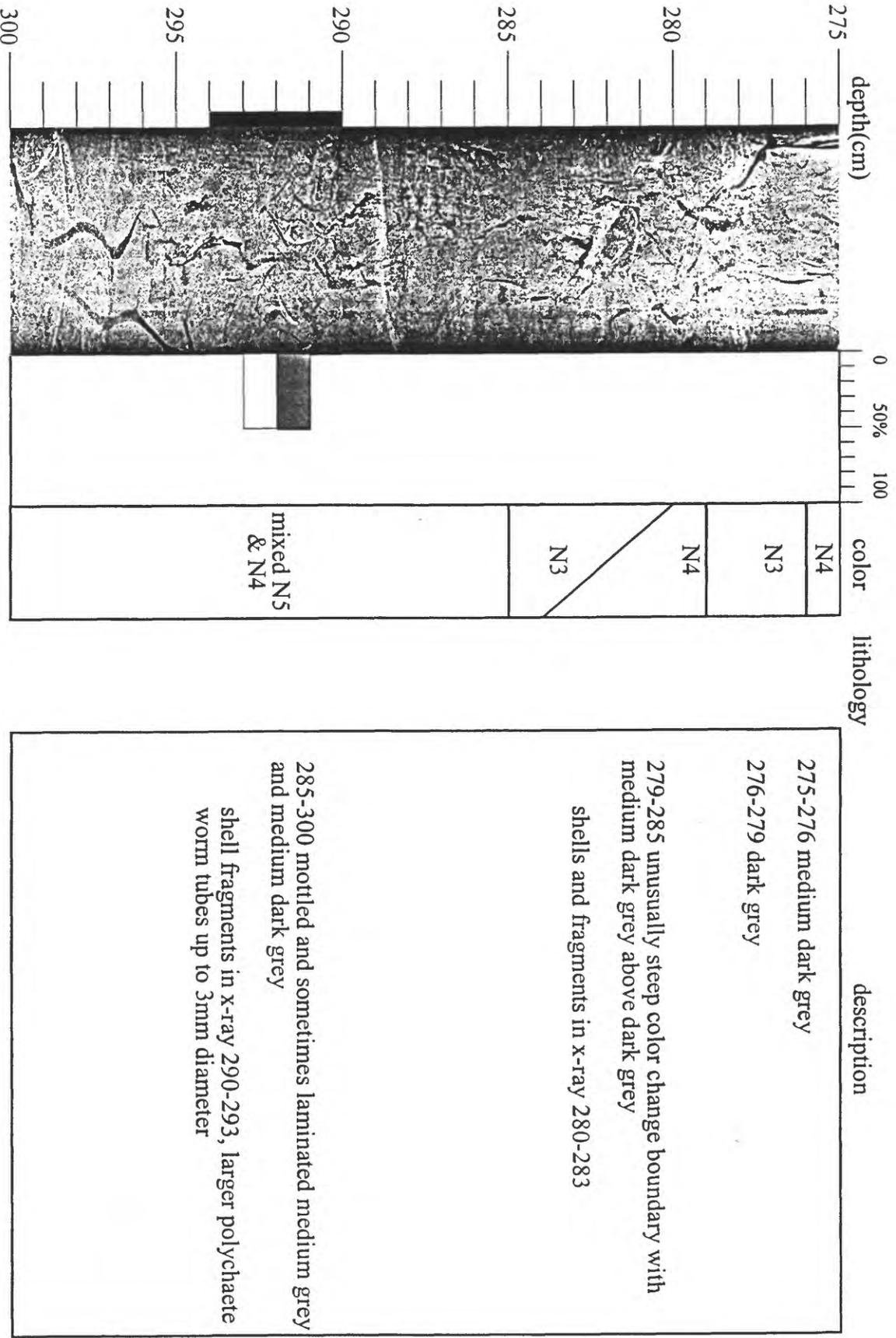
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Core LCPTK 1-1



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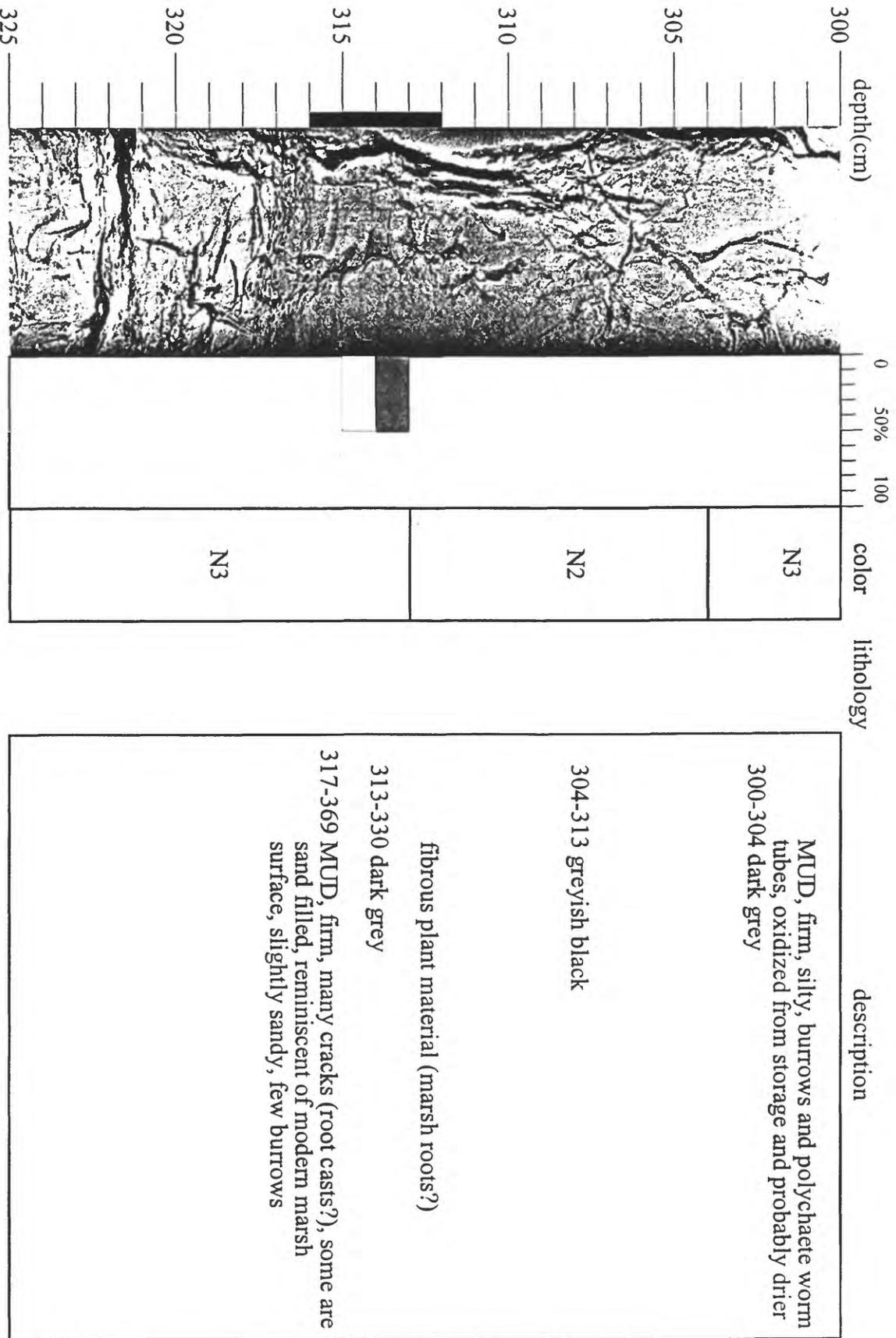
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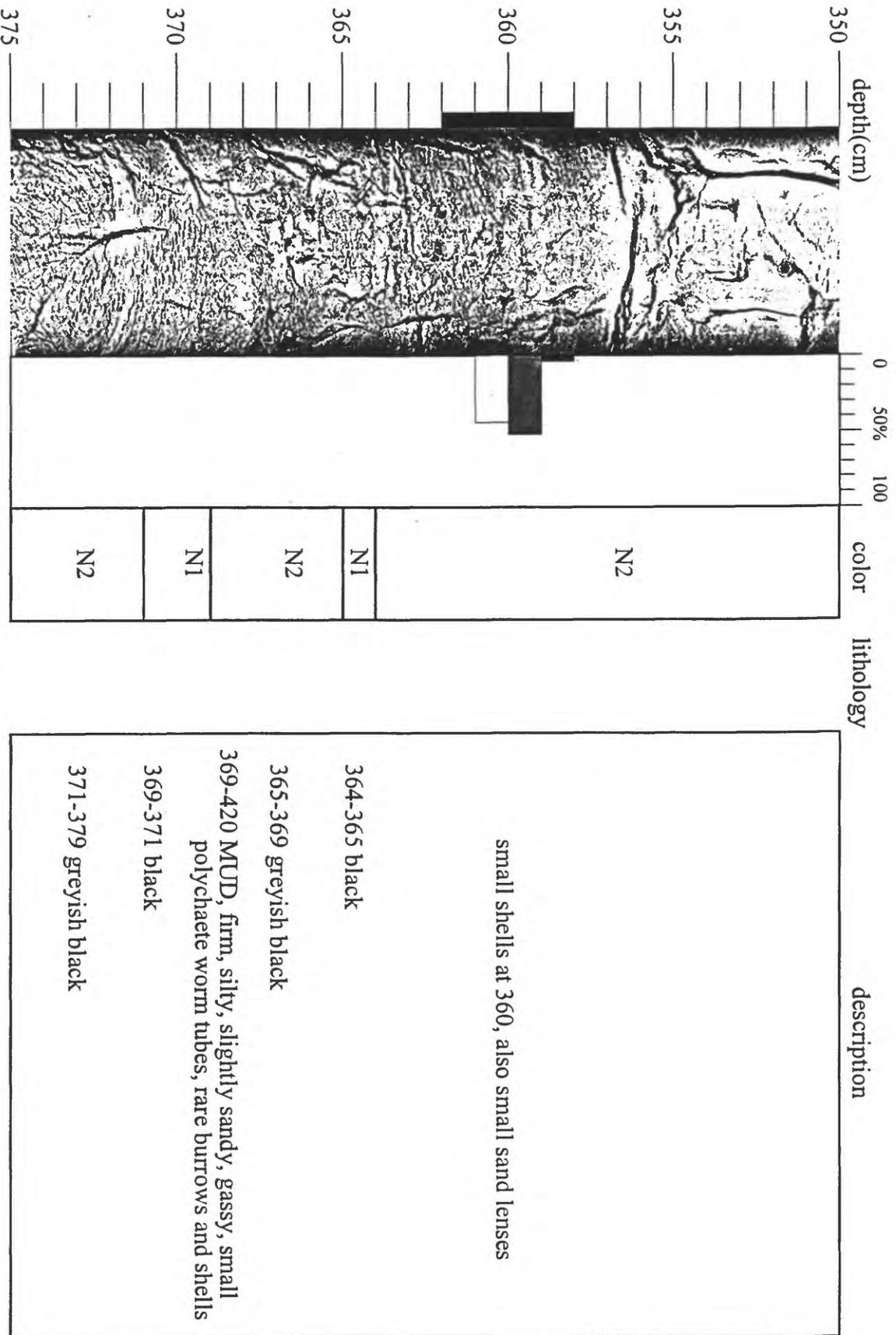
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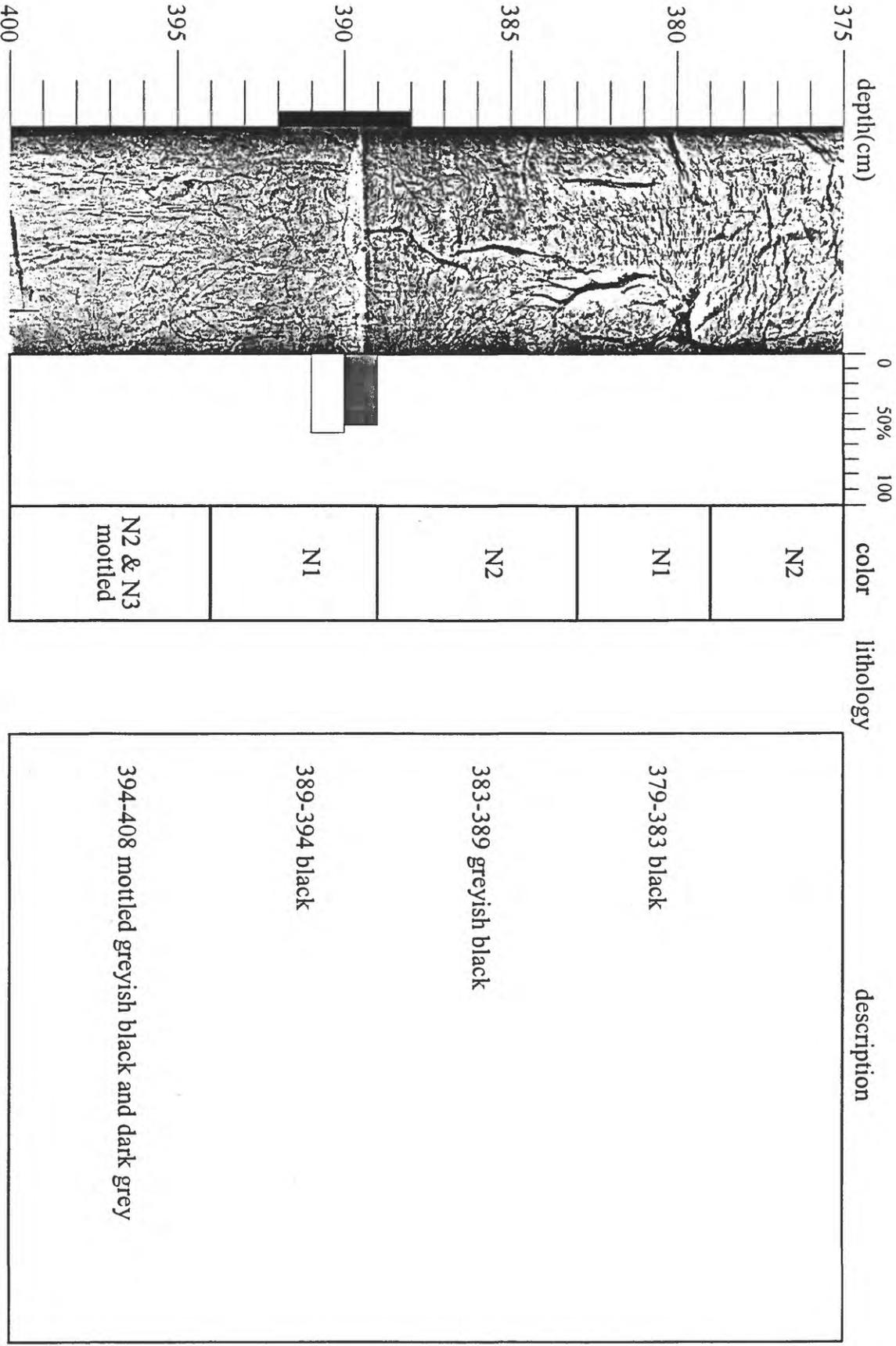
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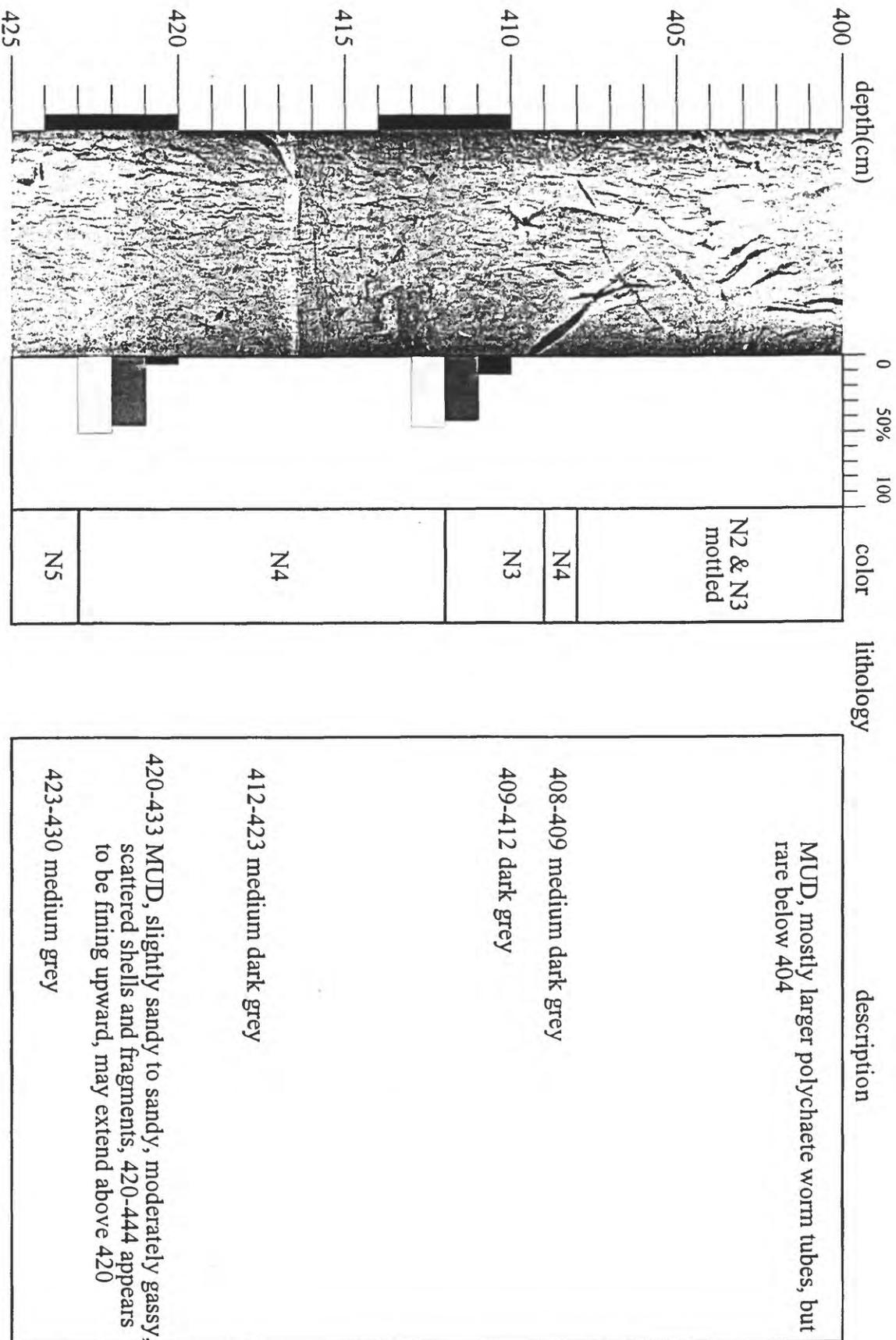
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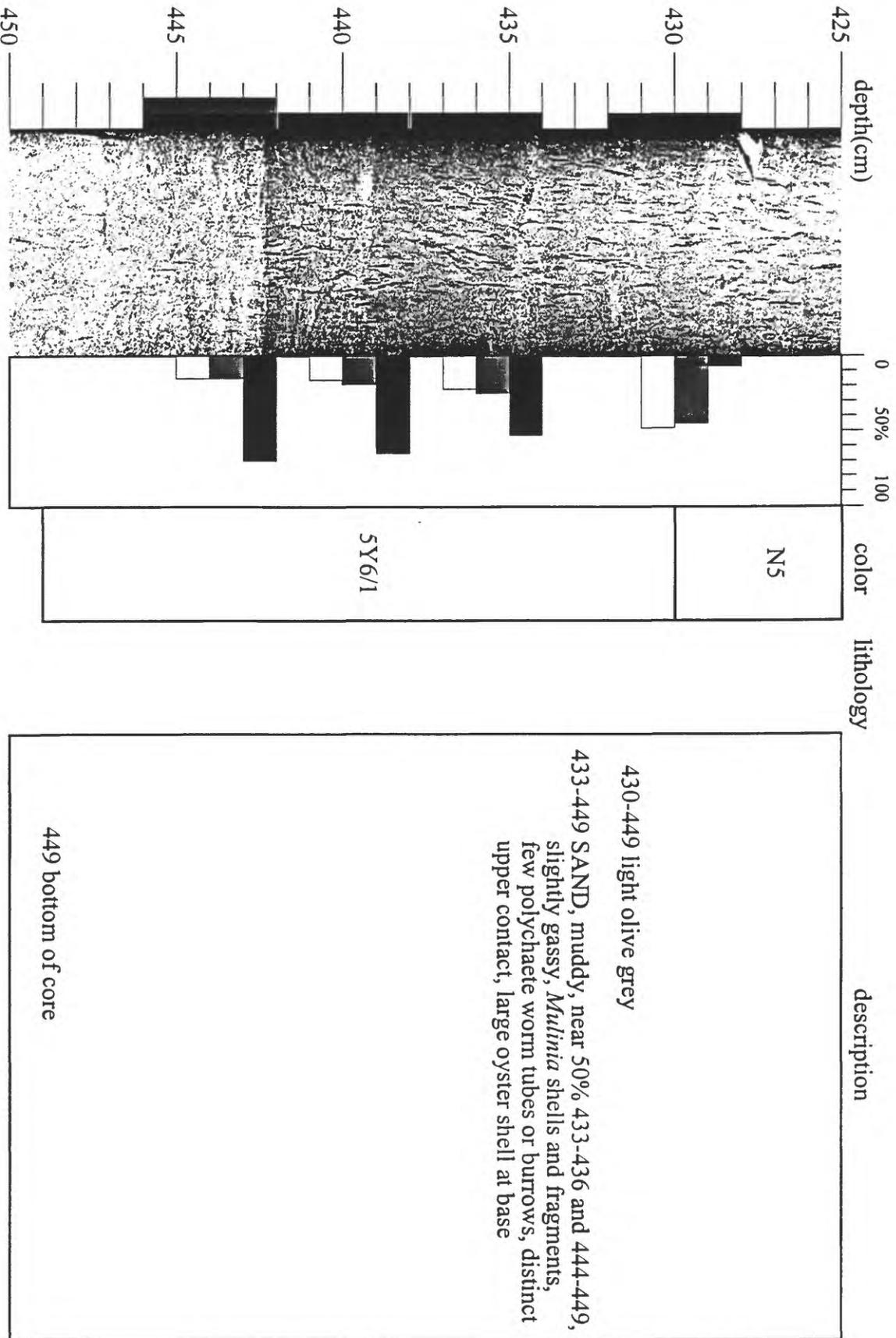
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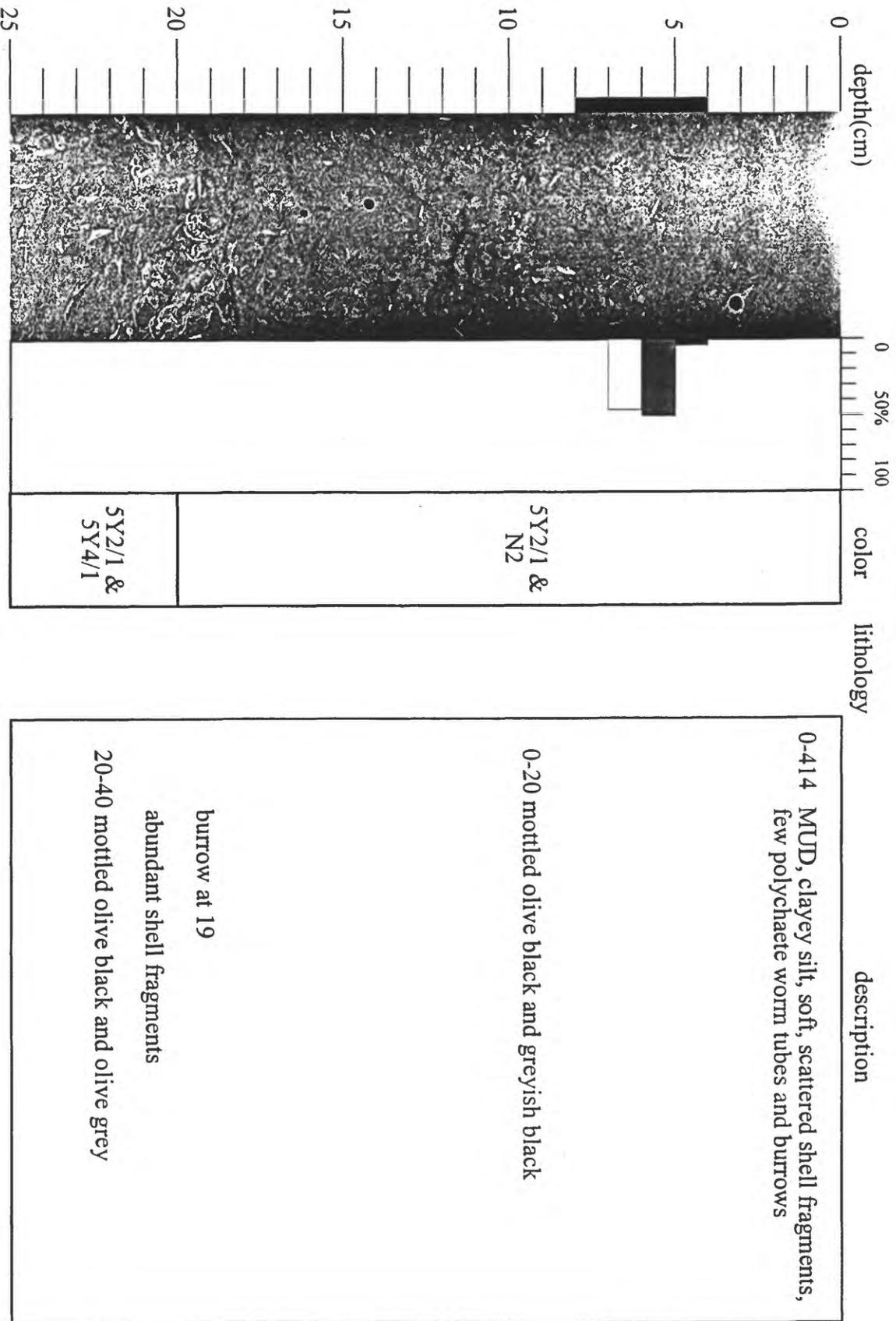
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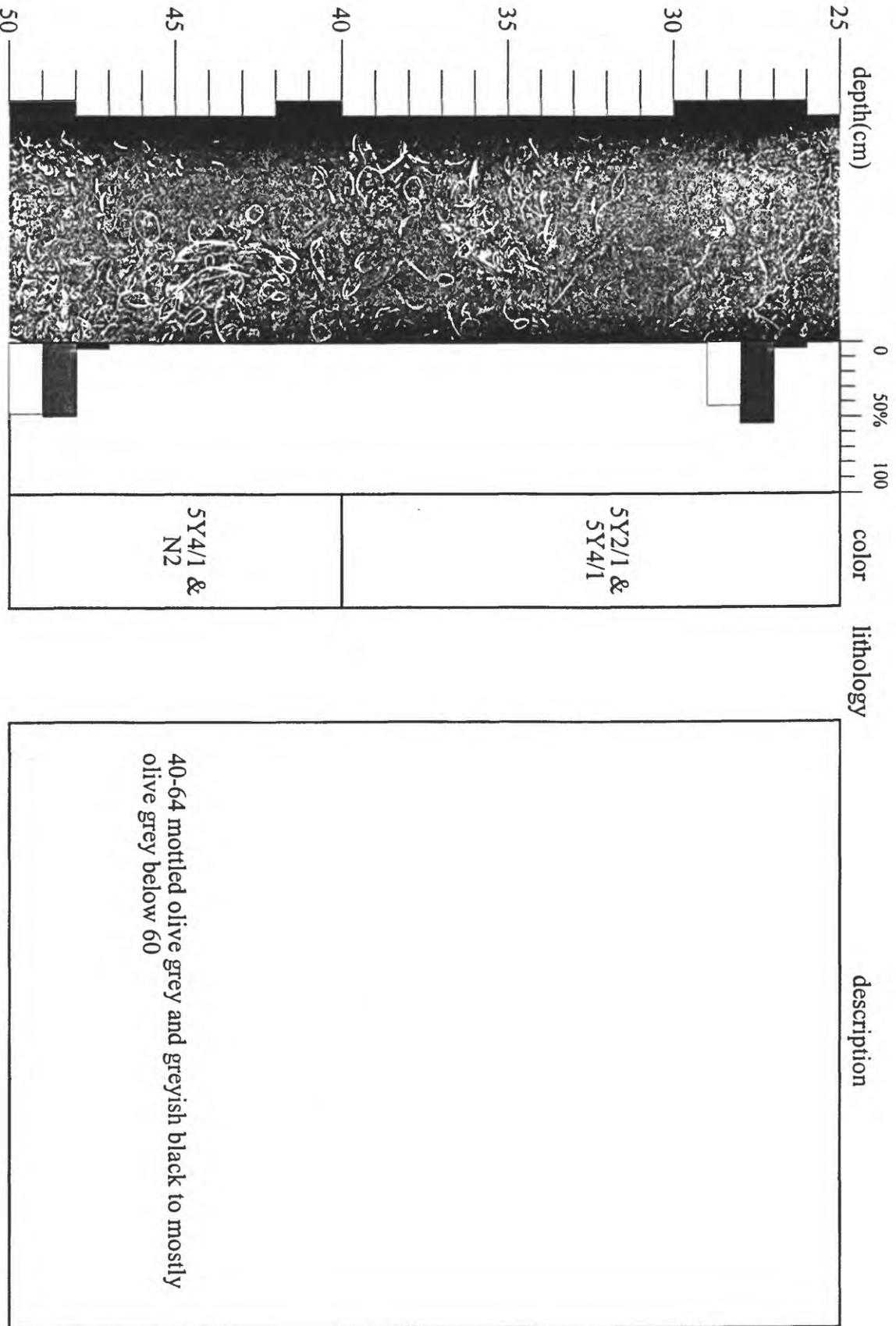
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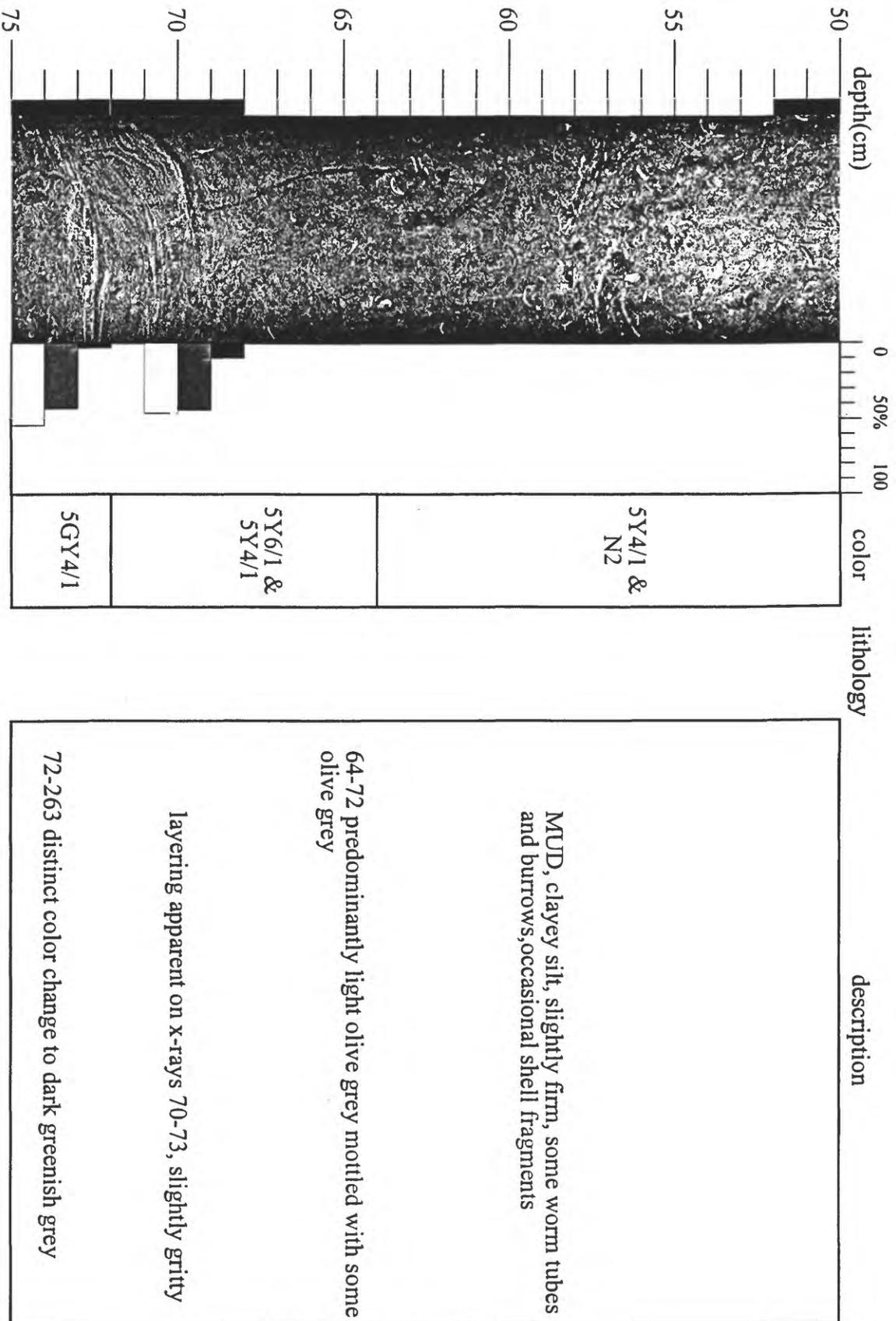
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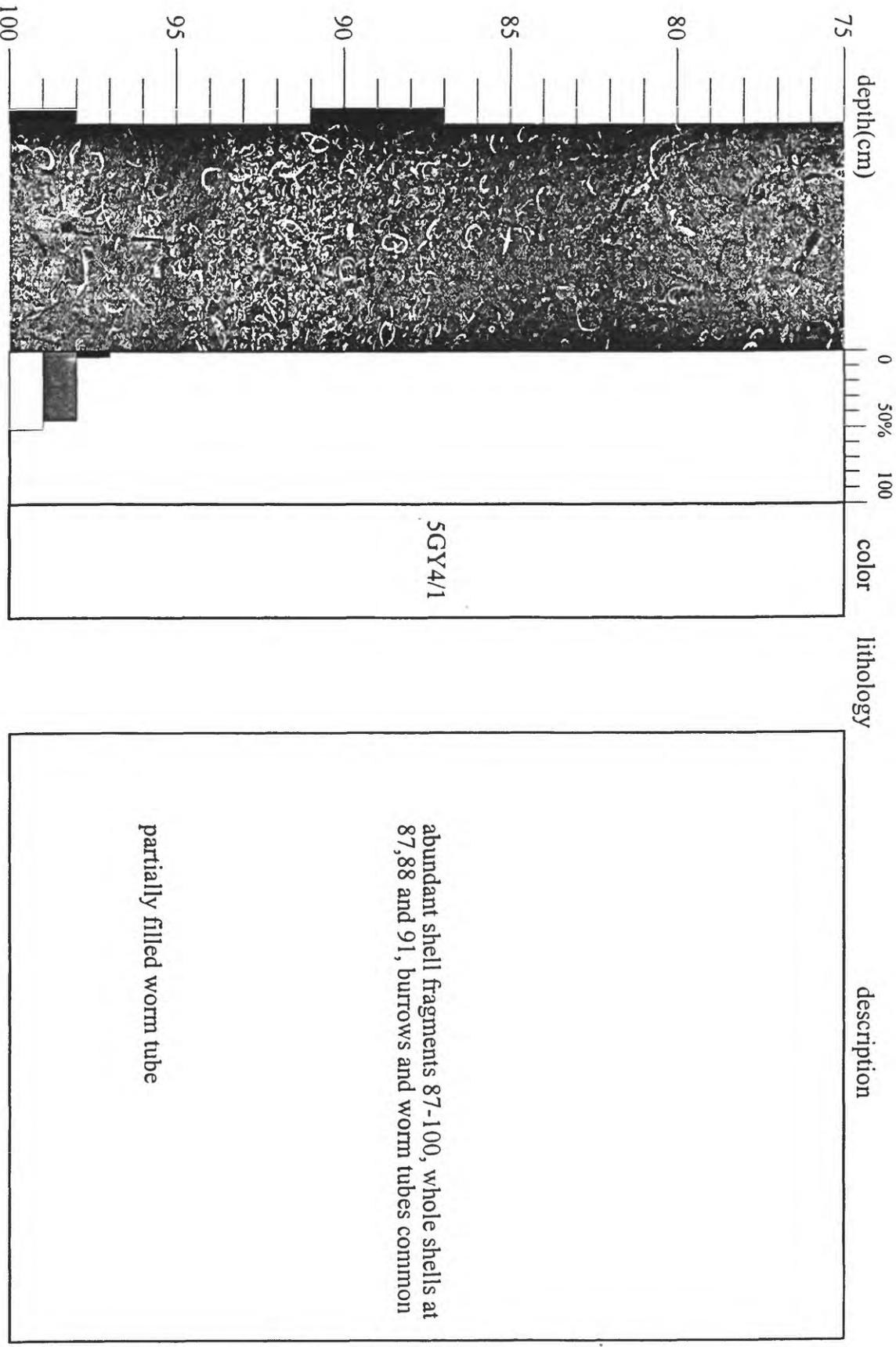
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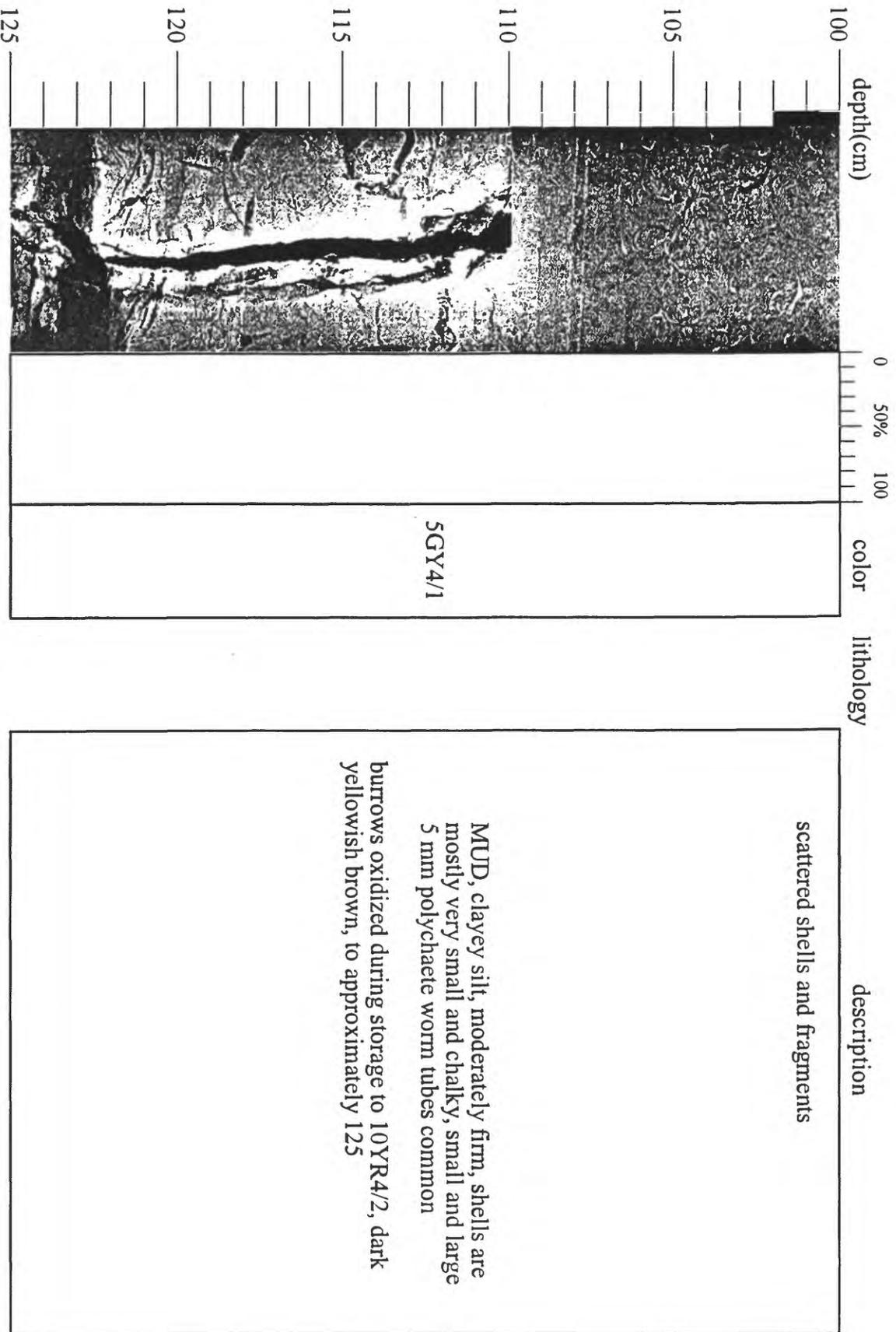
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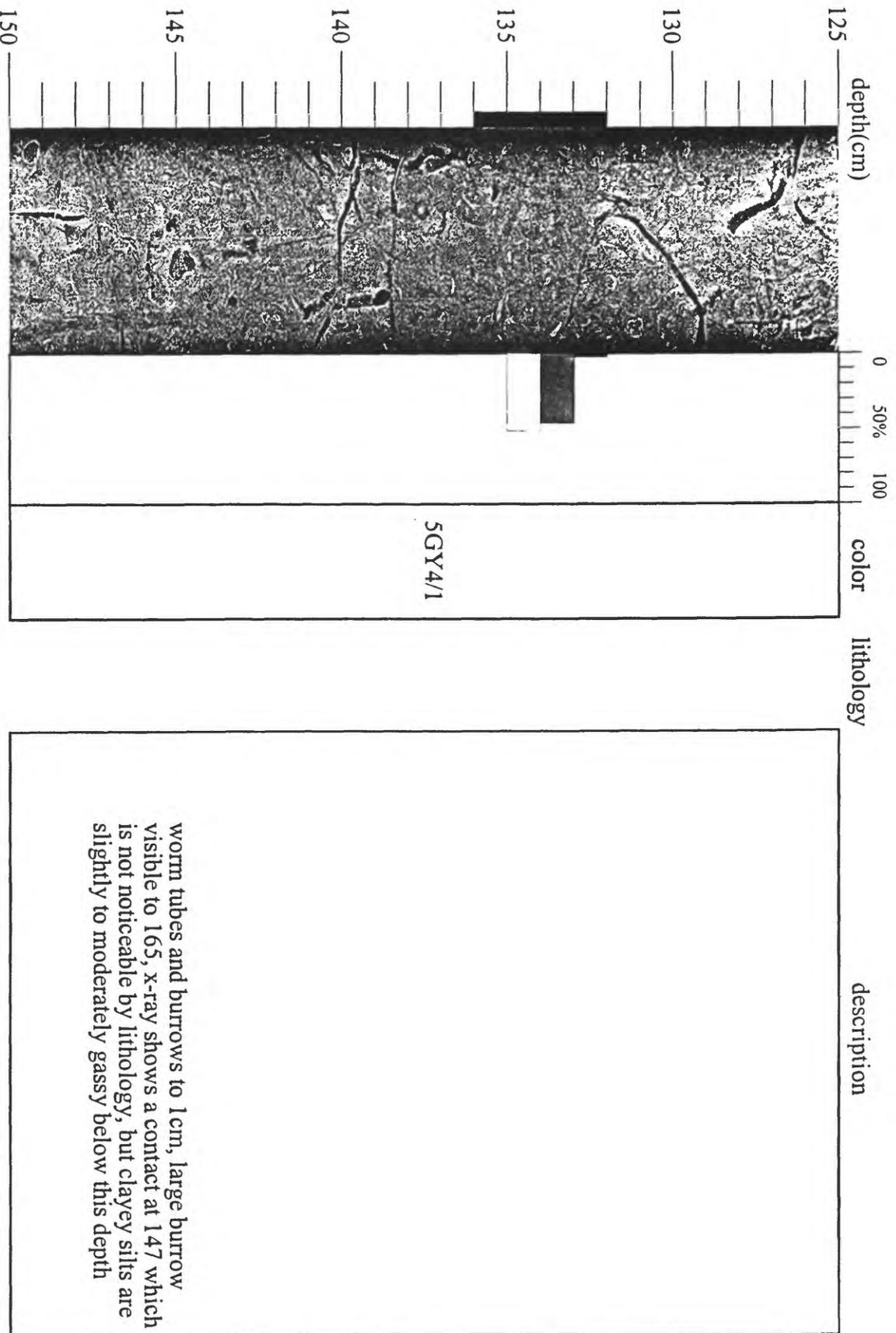
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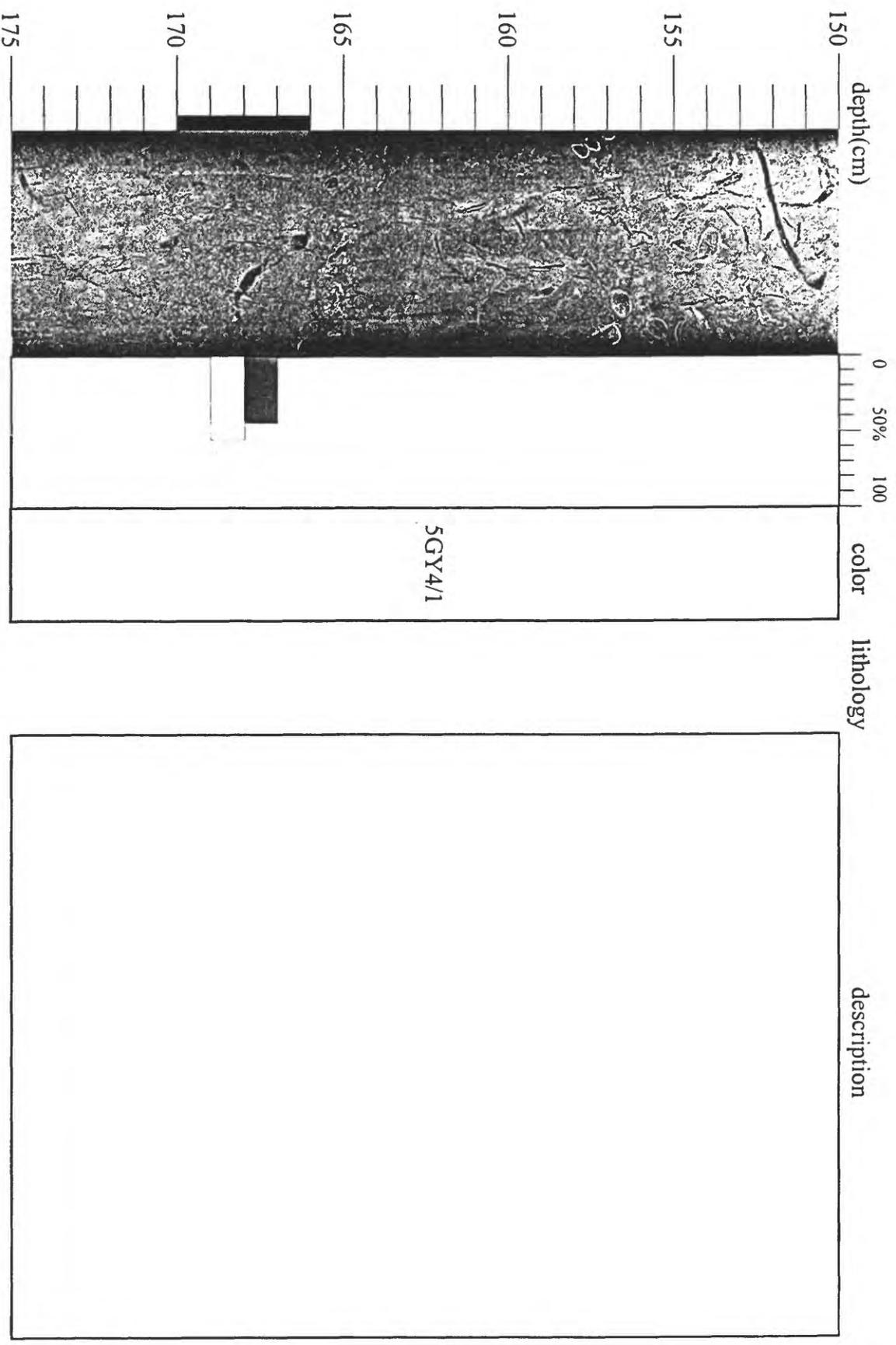
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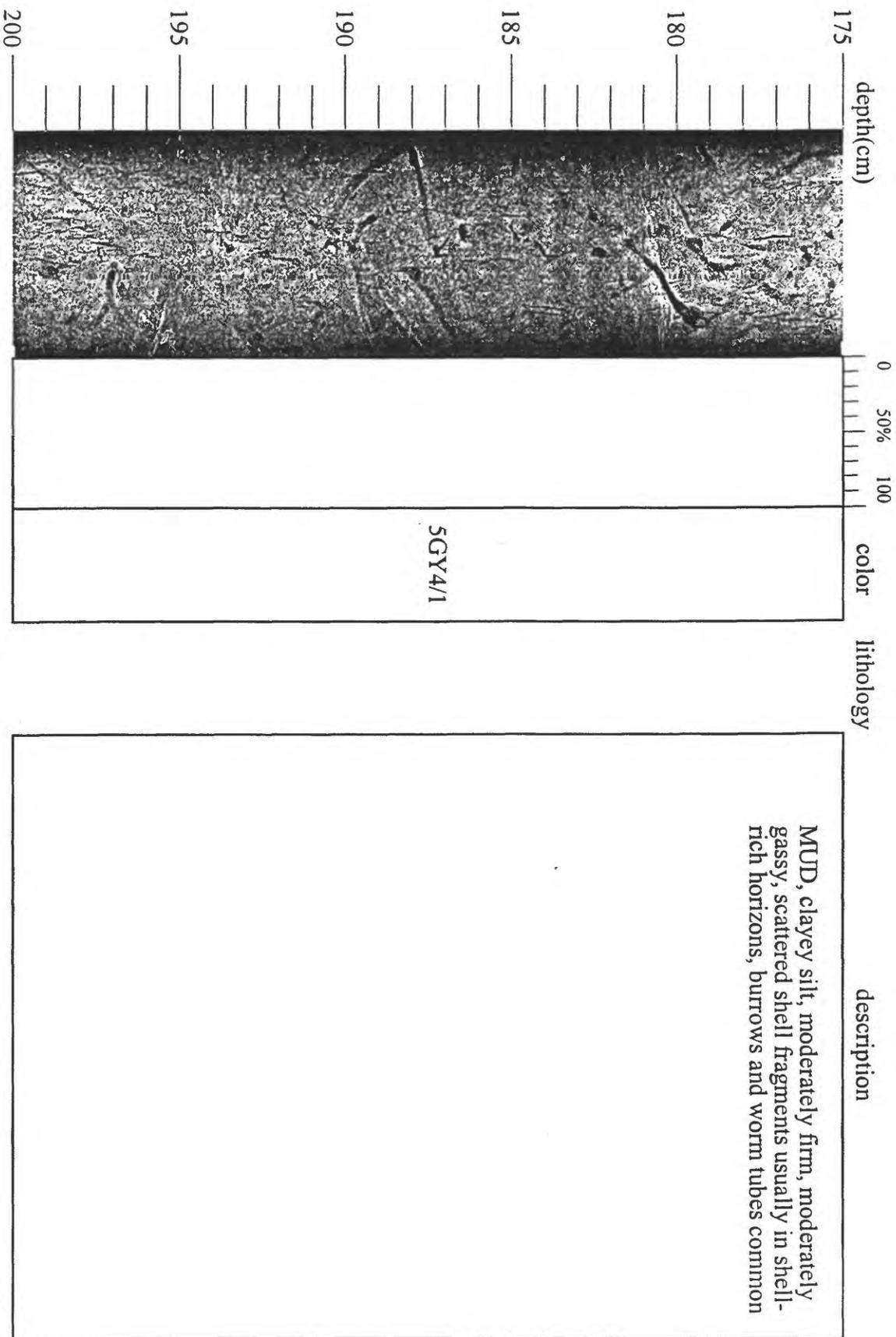
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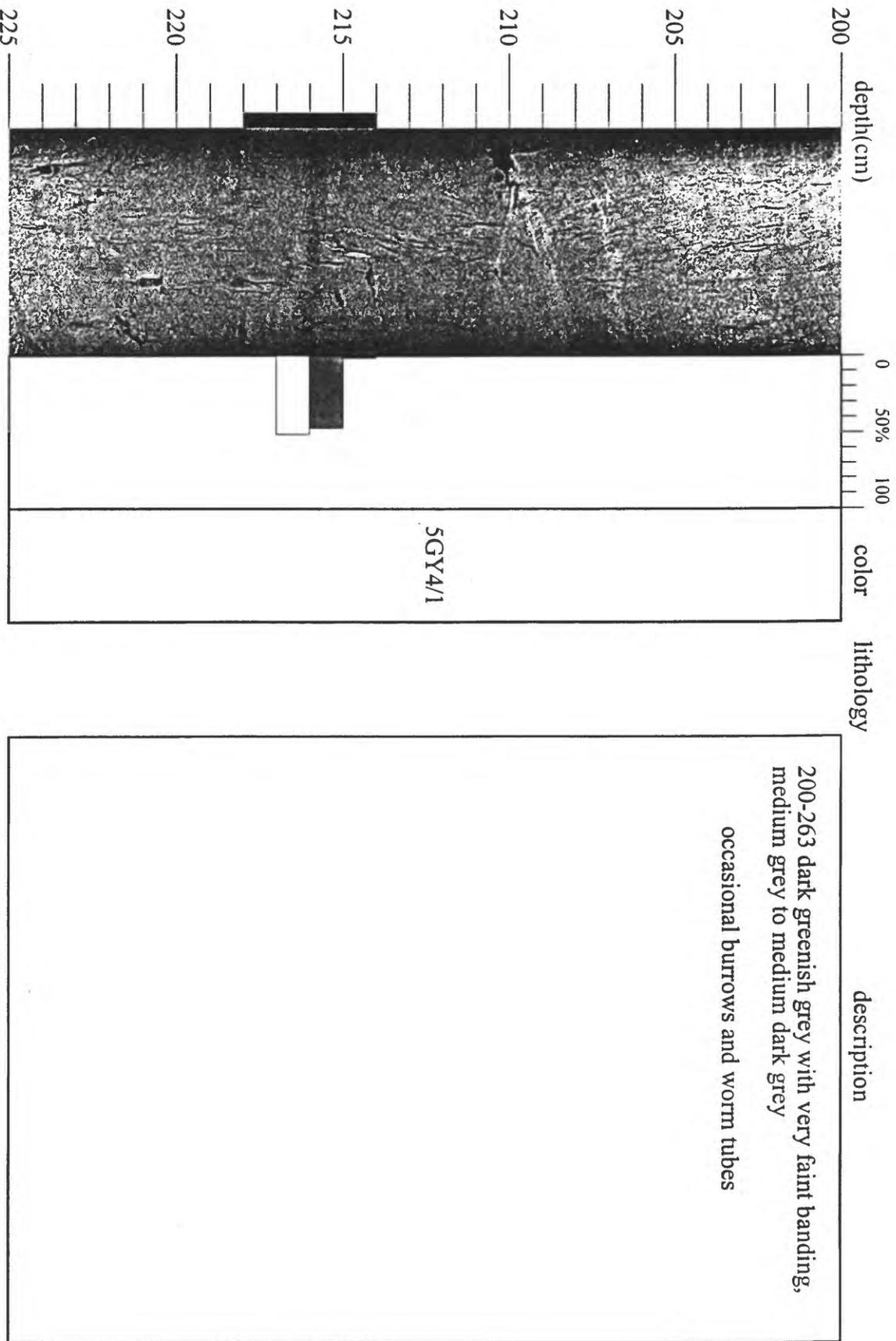
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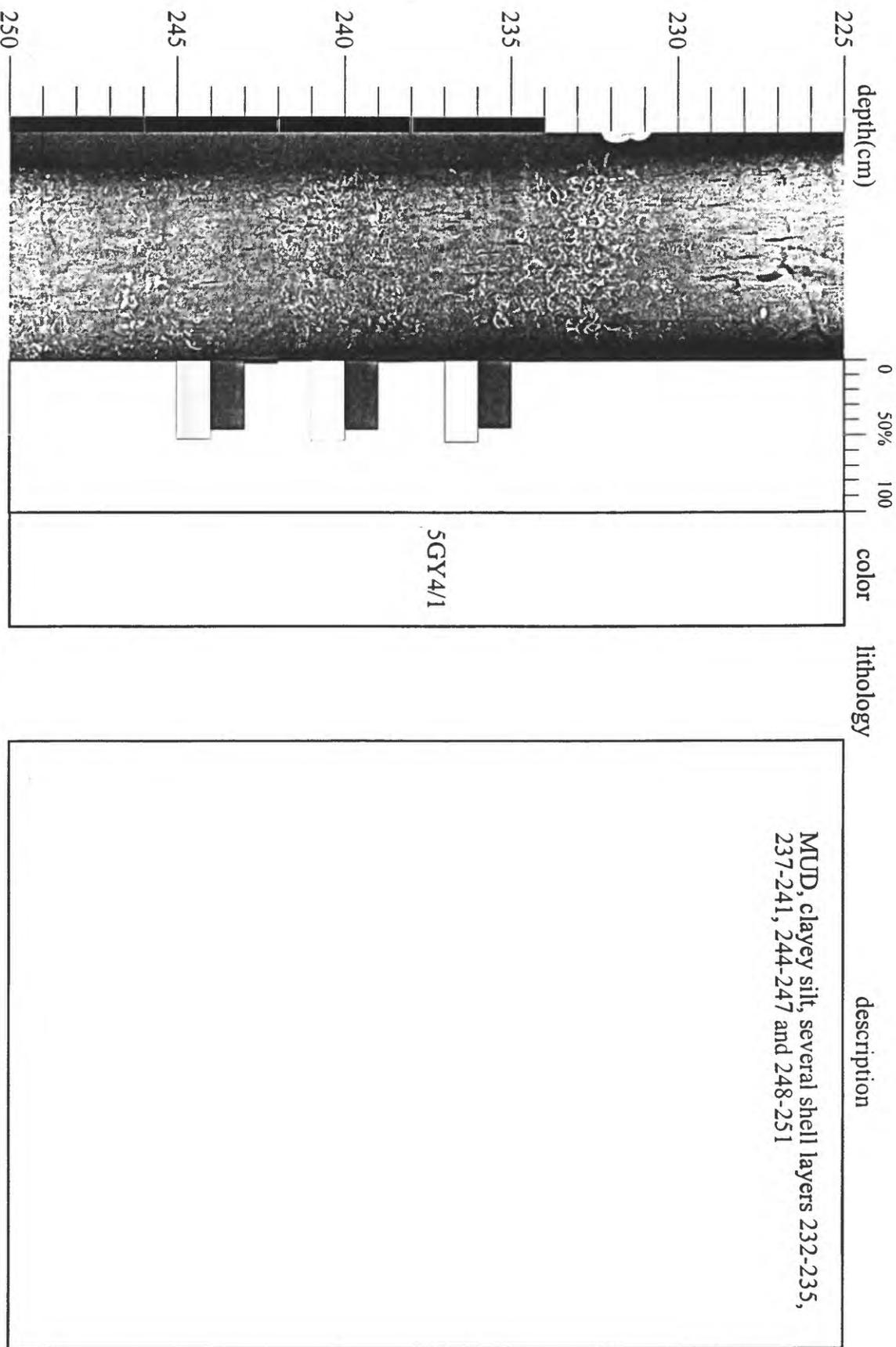
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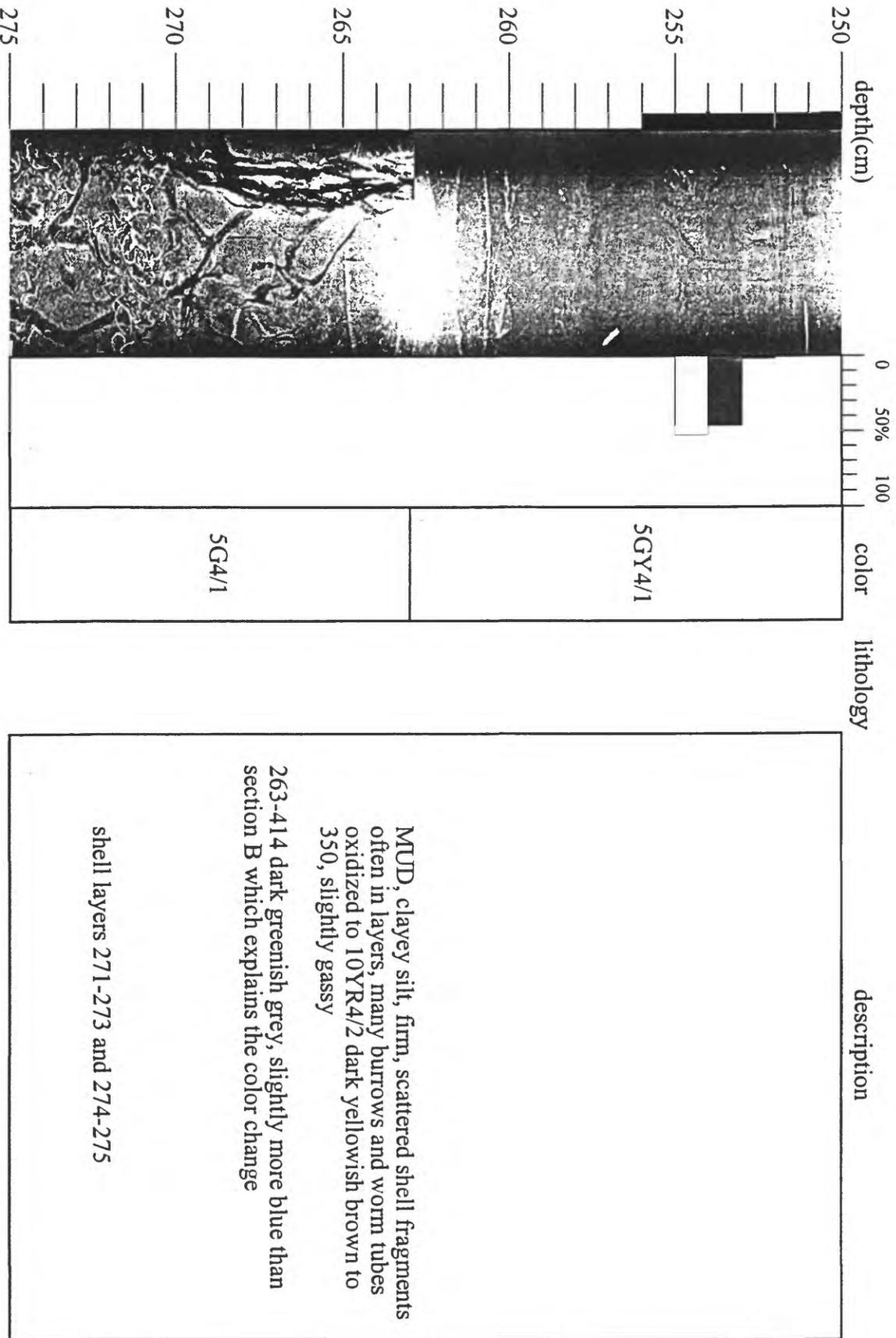
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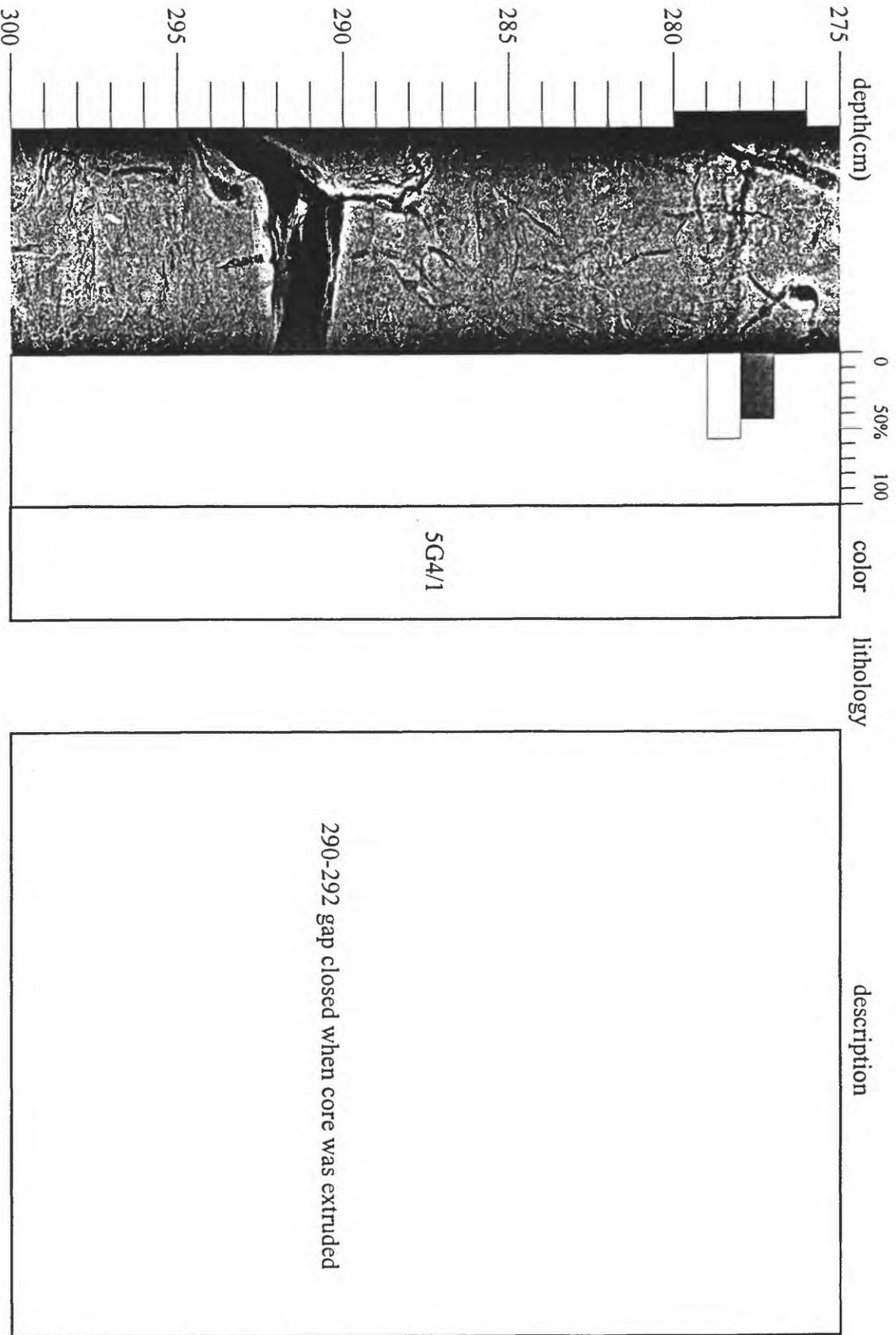
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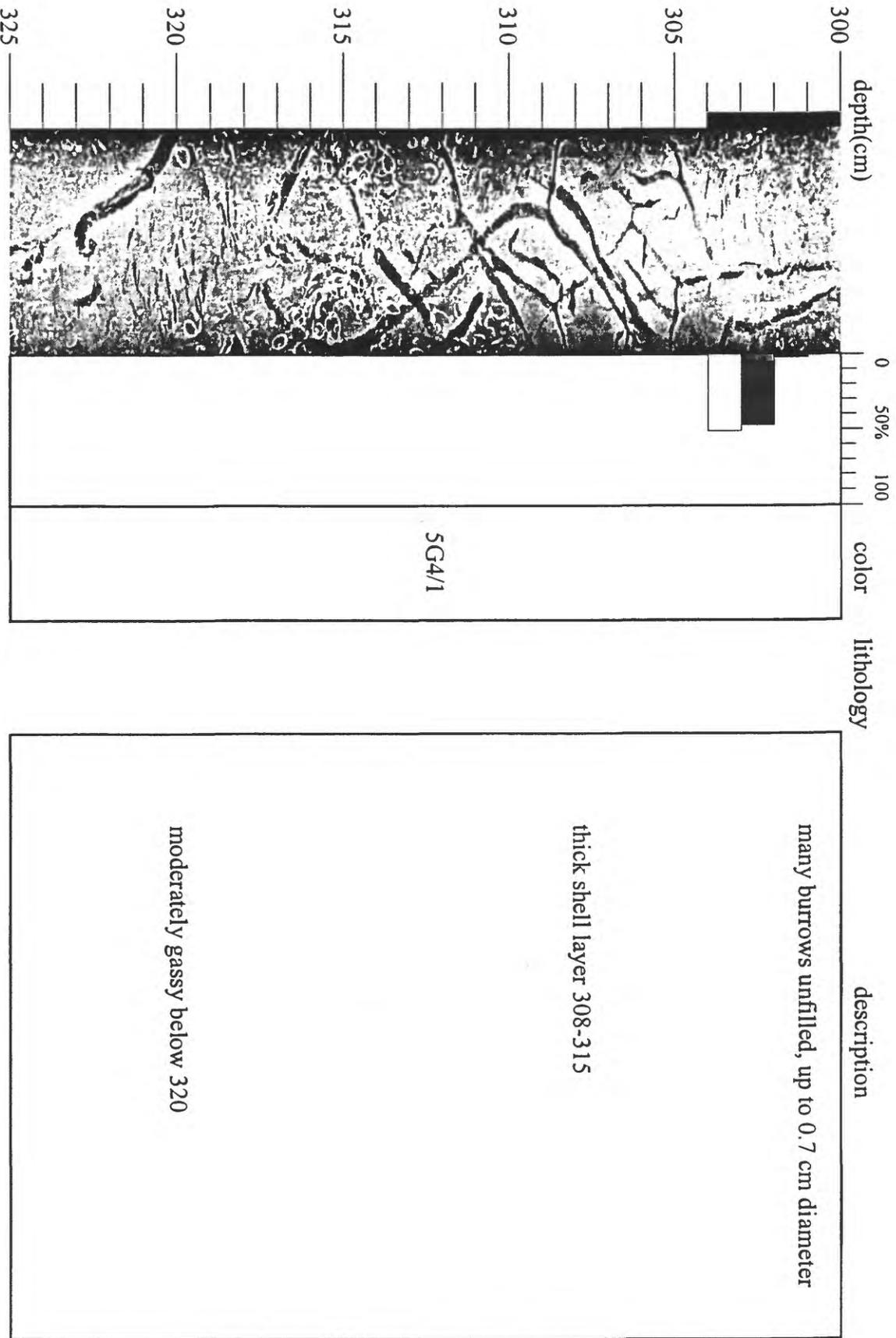
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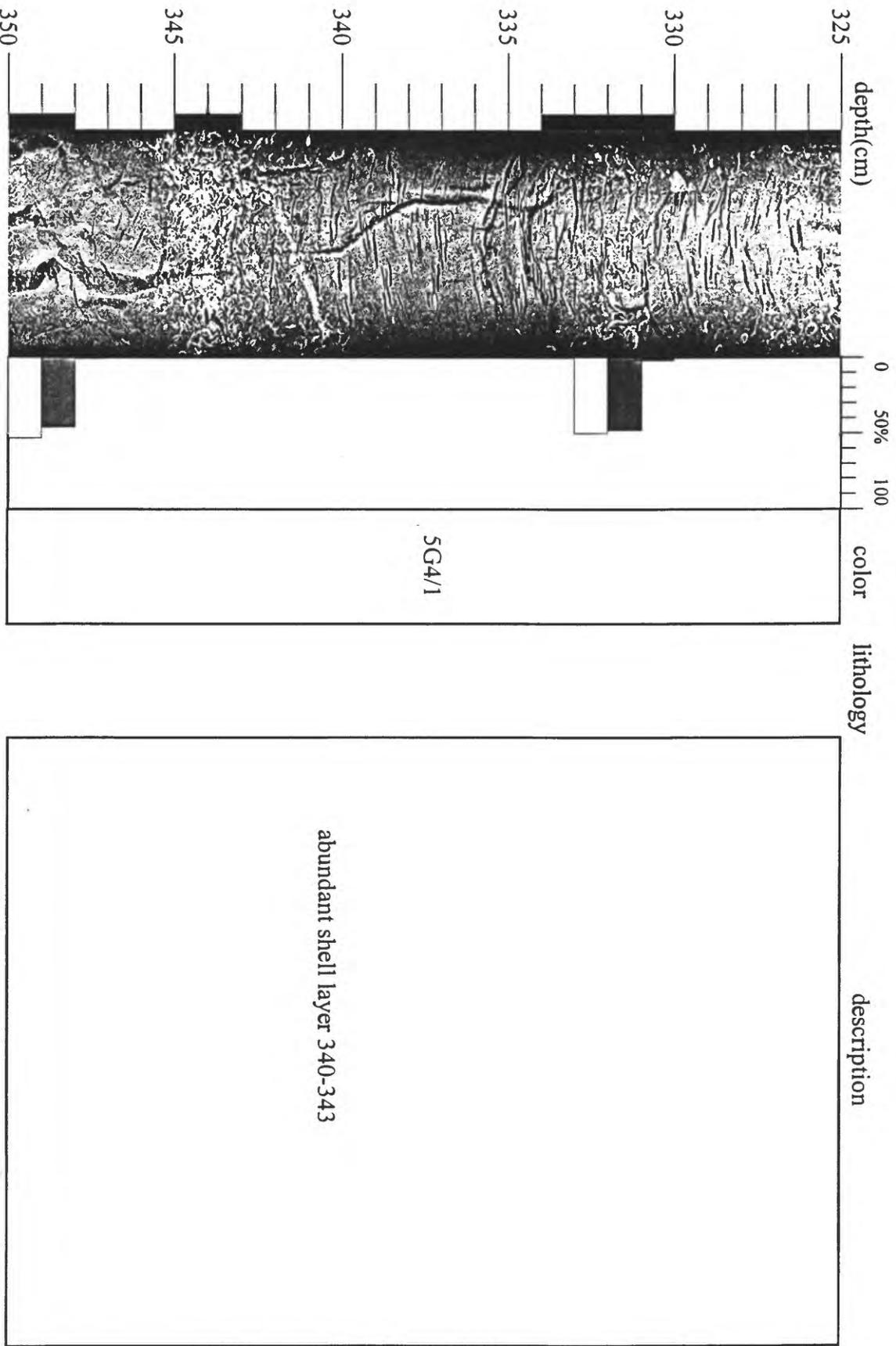
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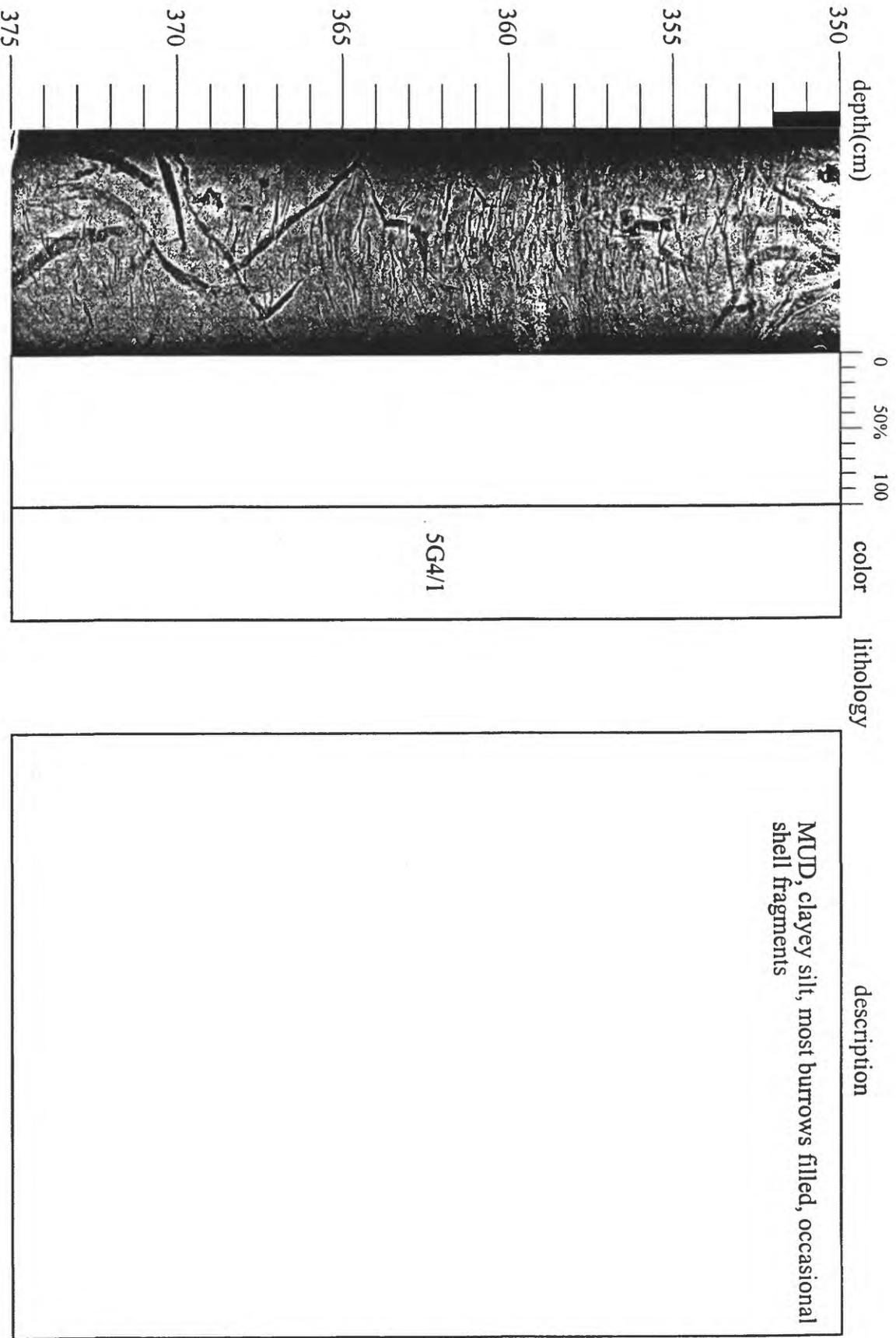
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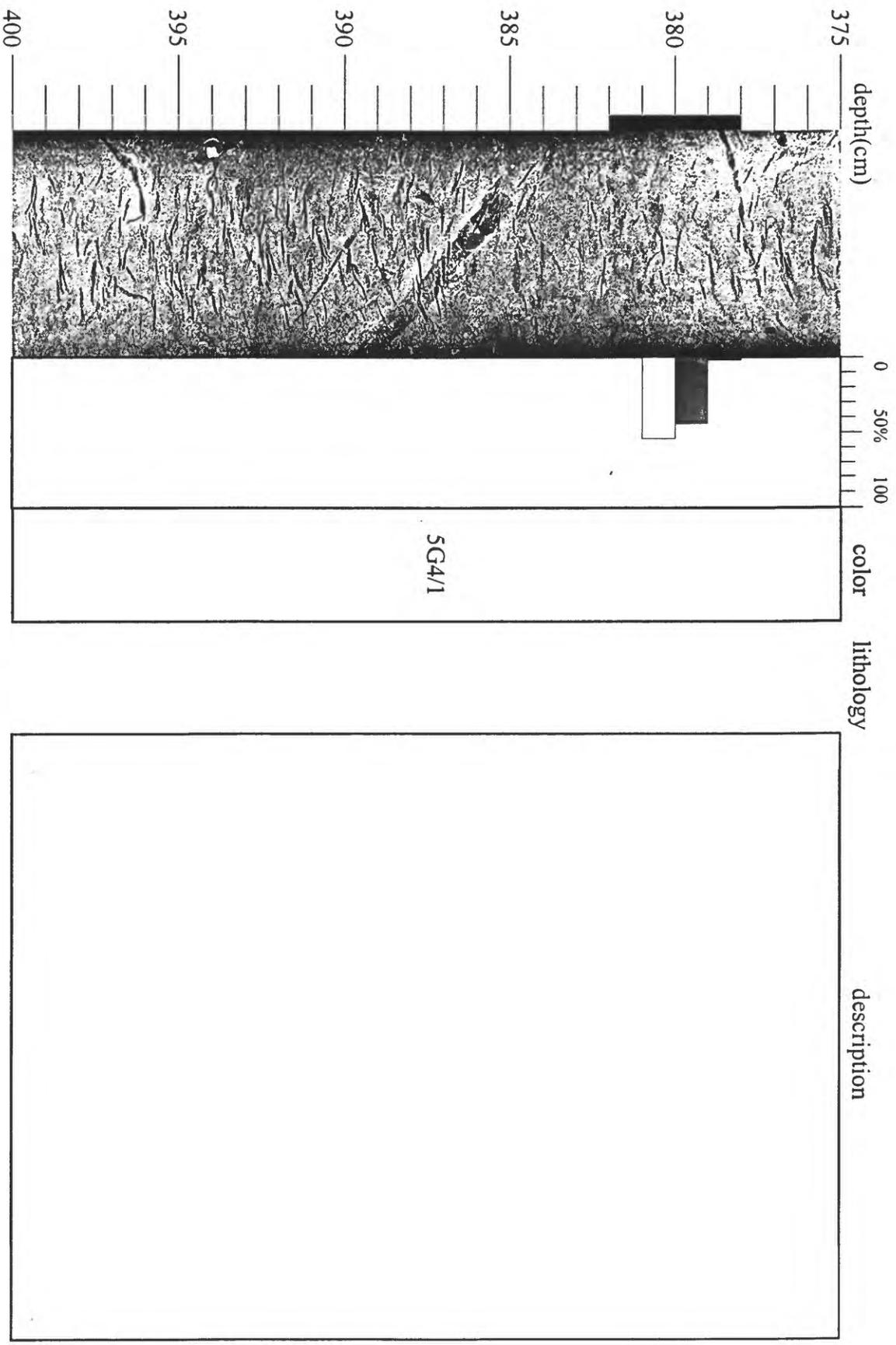
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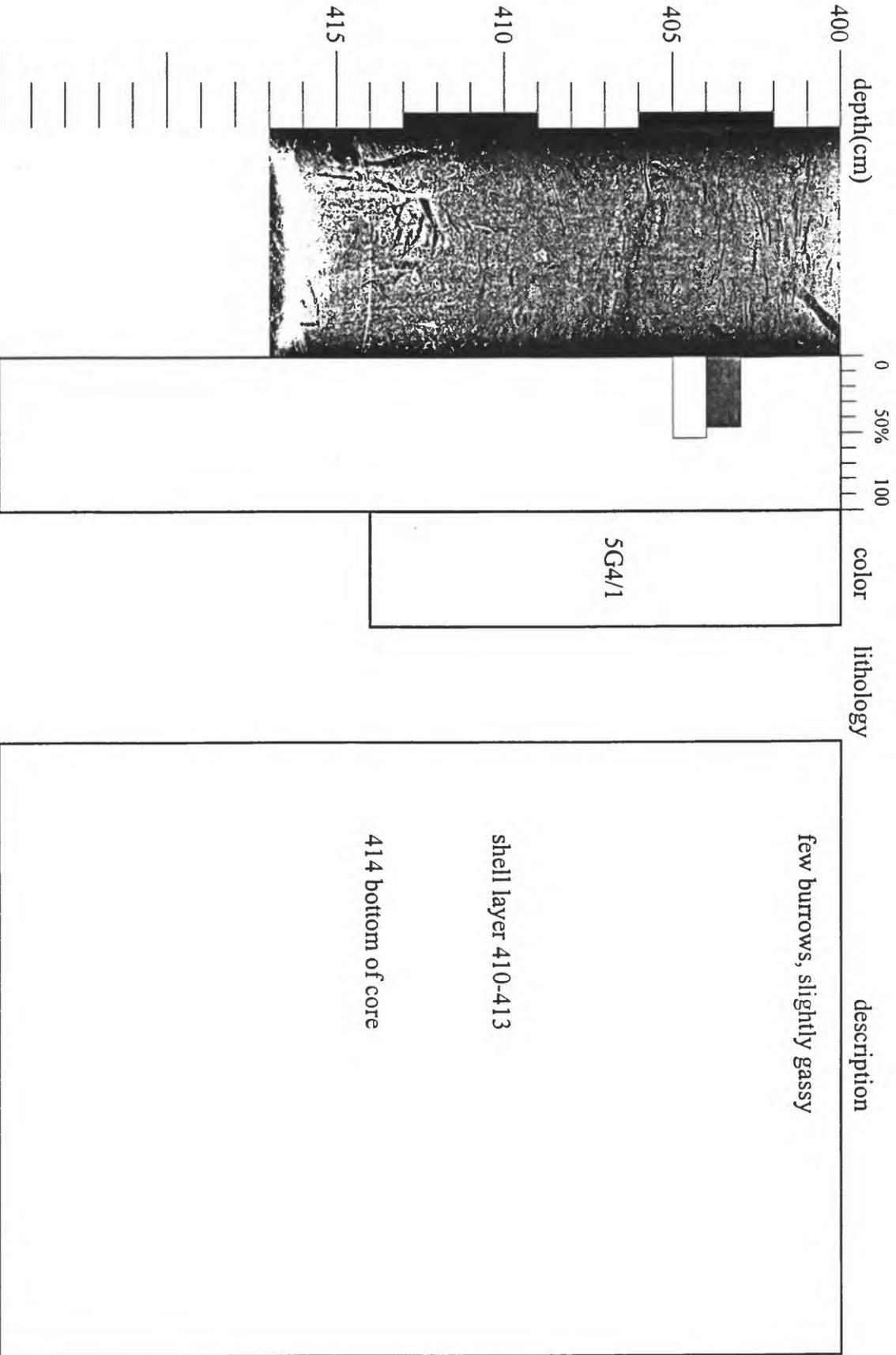
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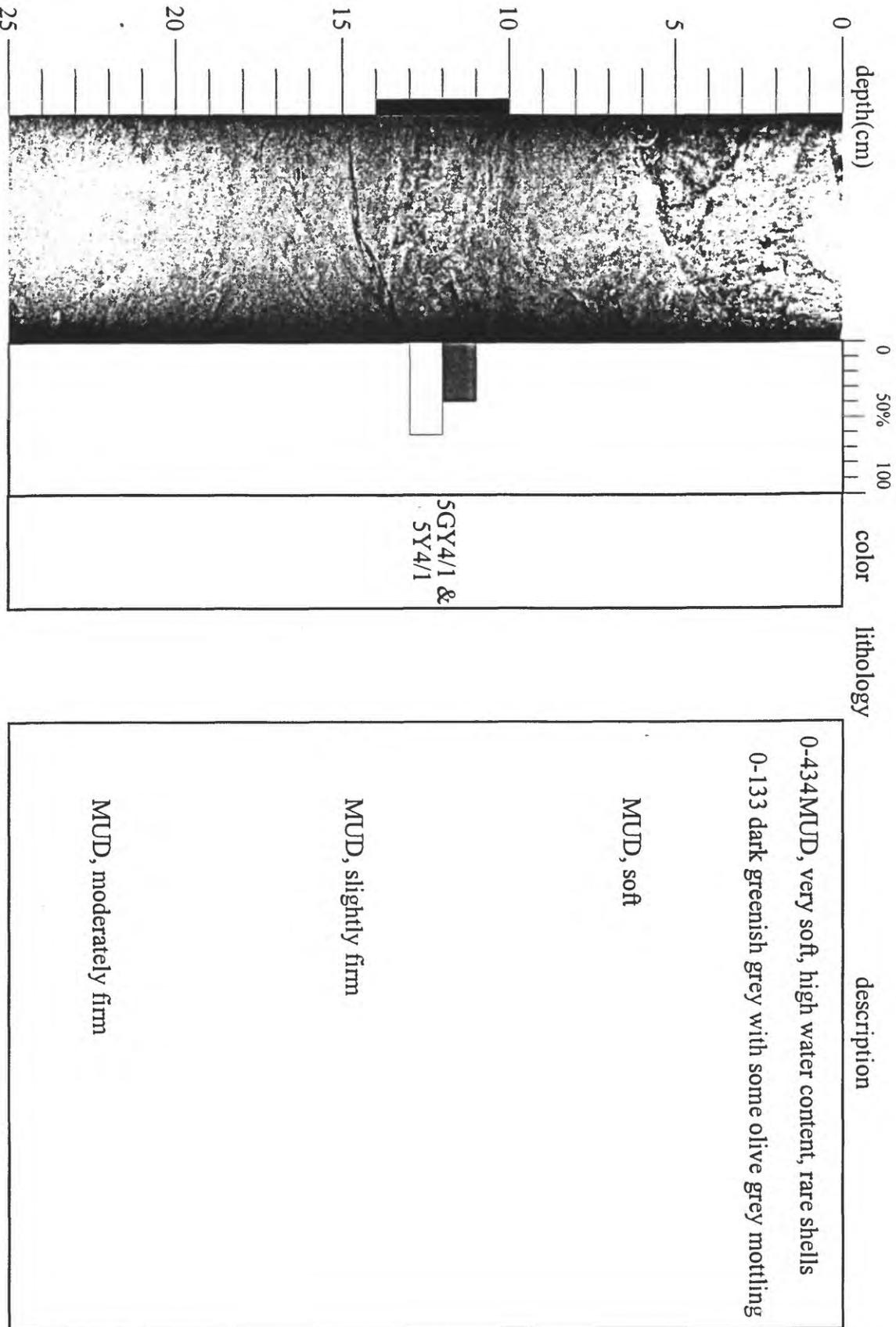
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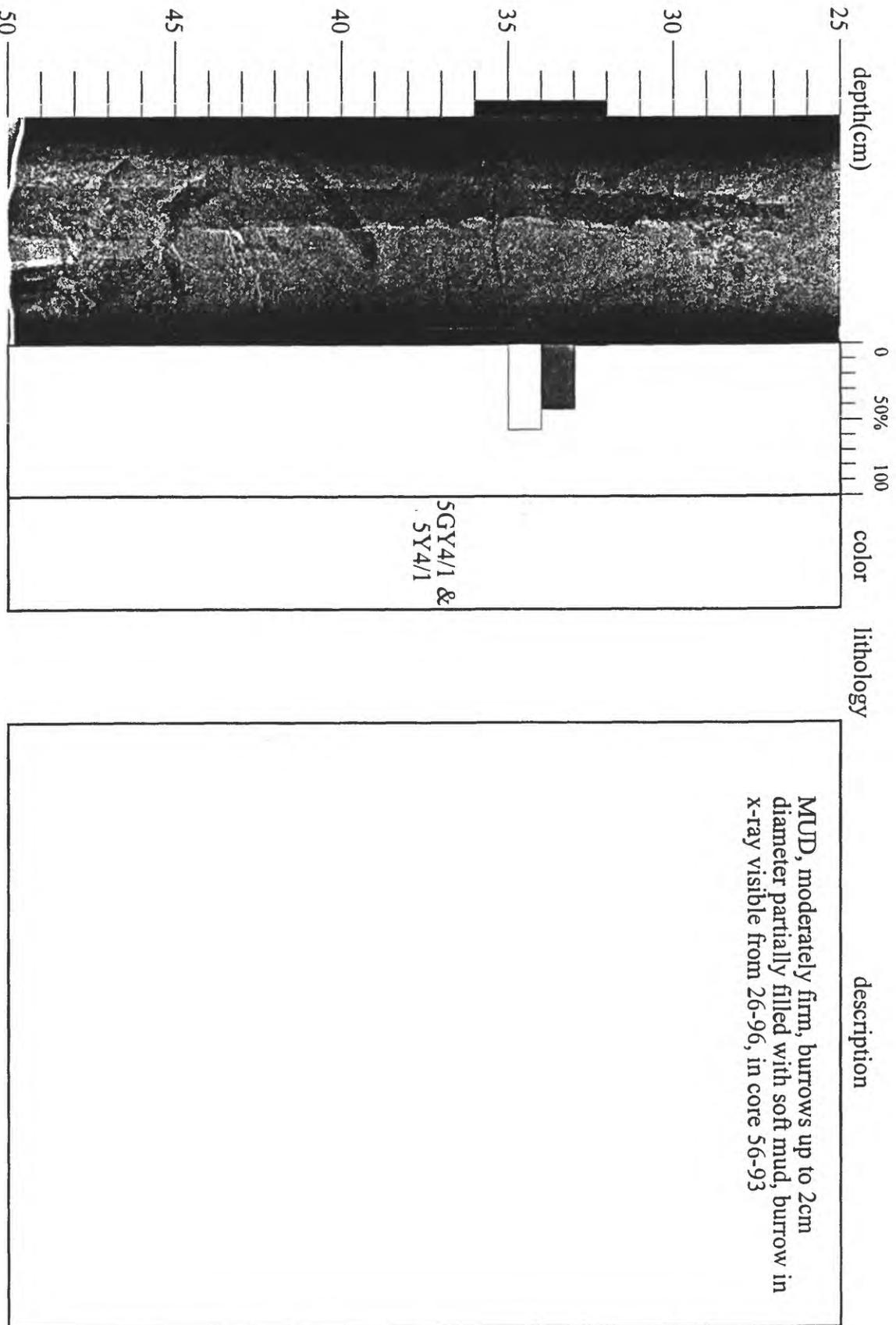
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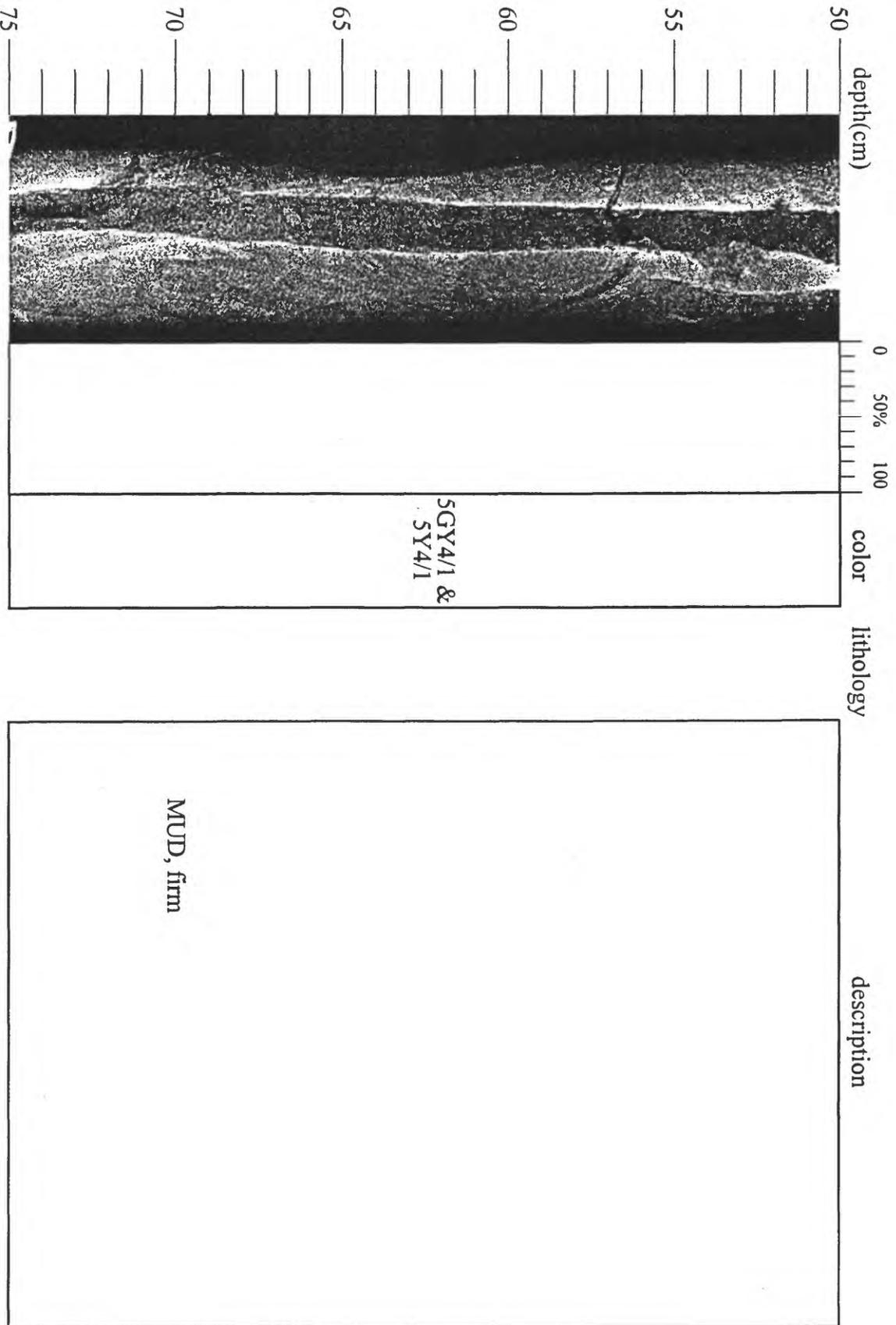
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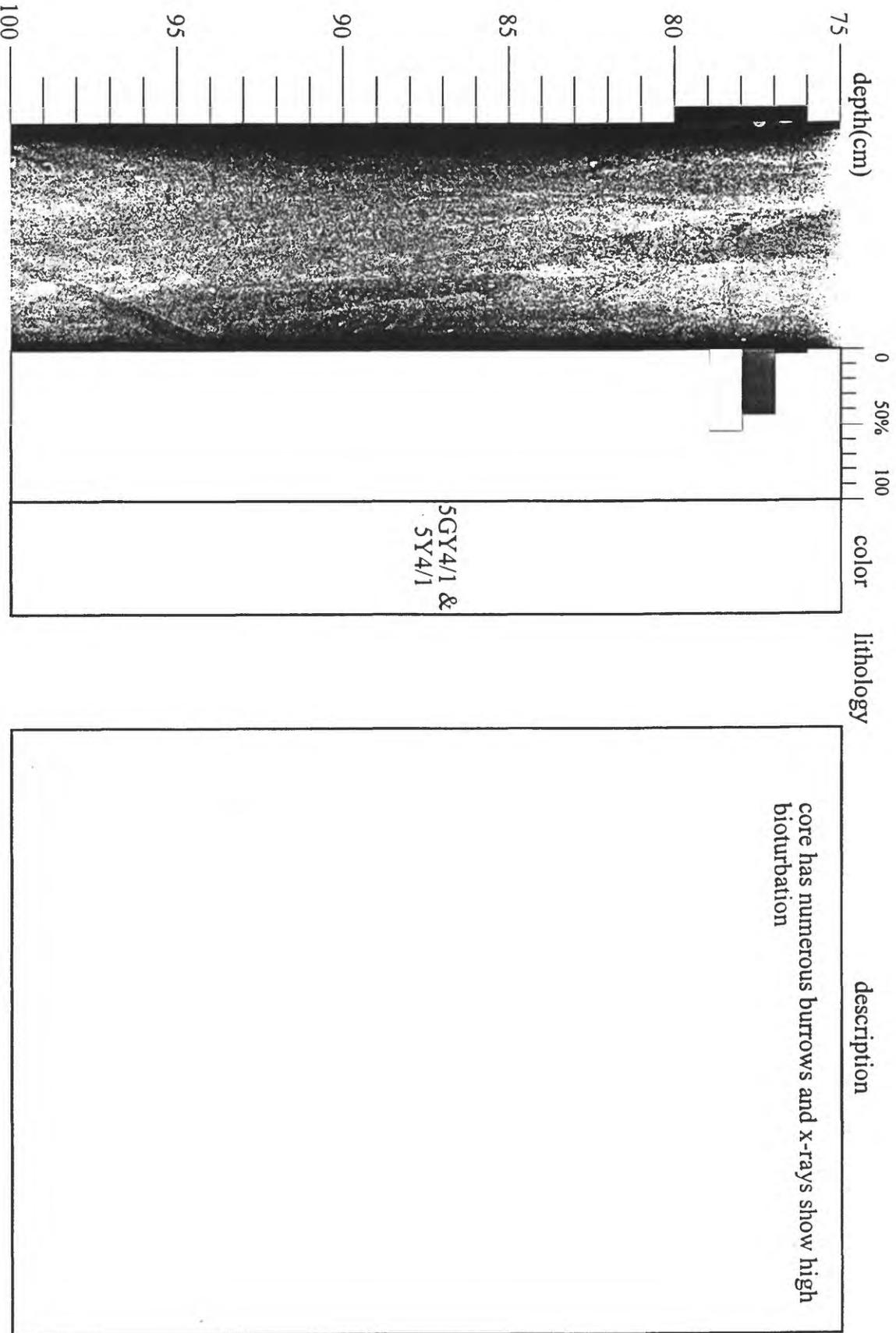
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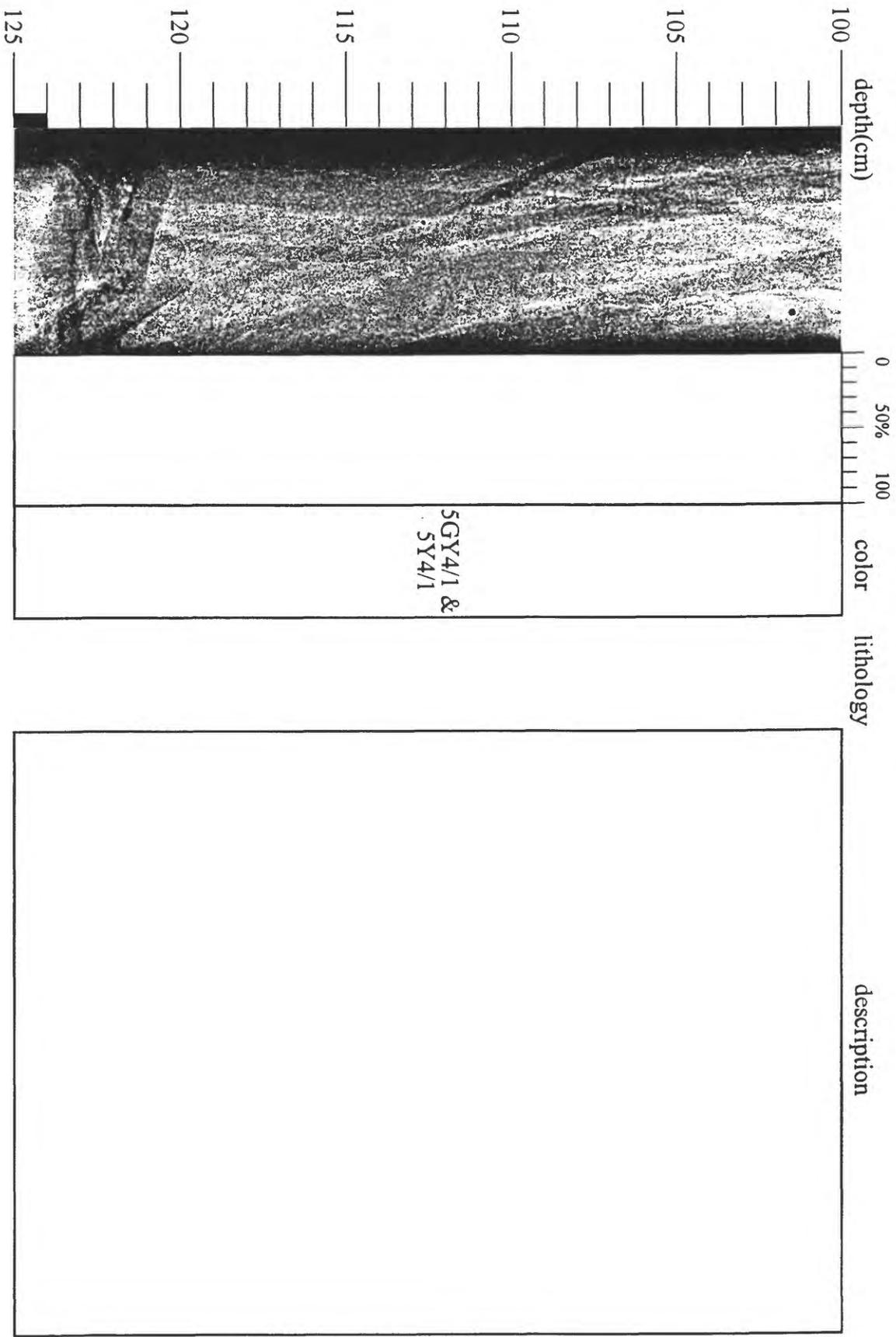
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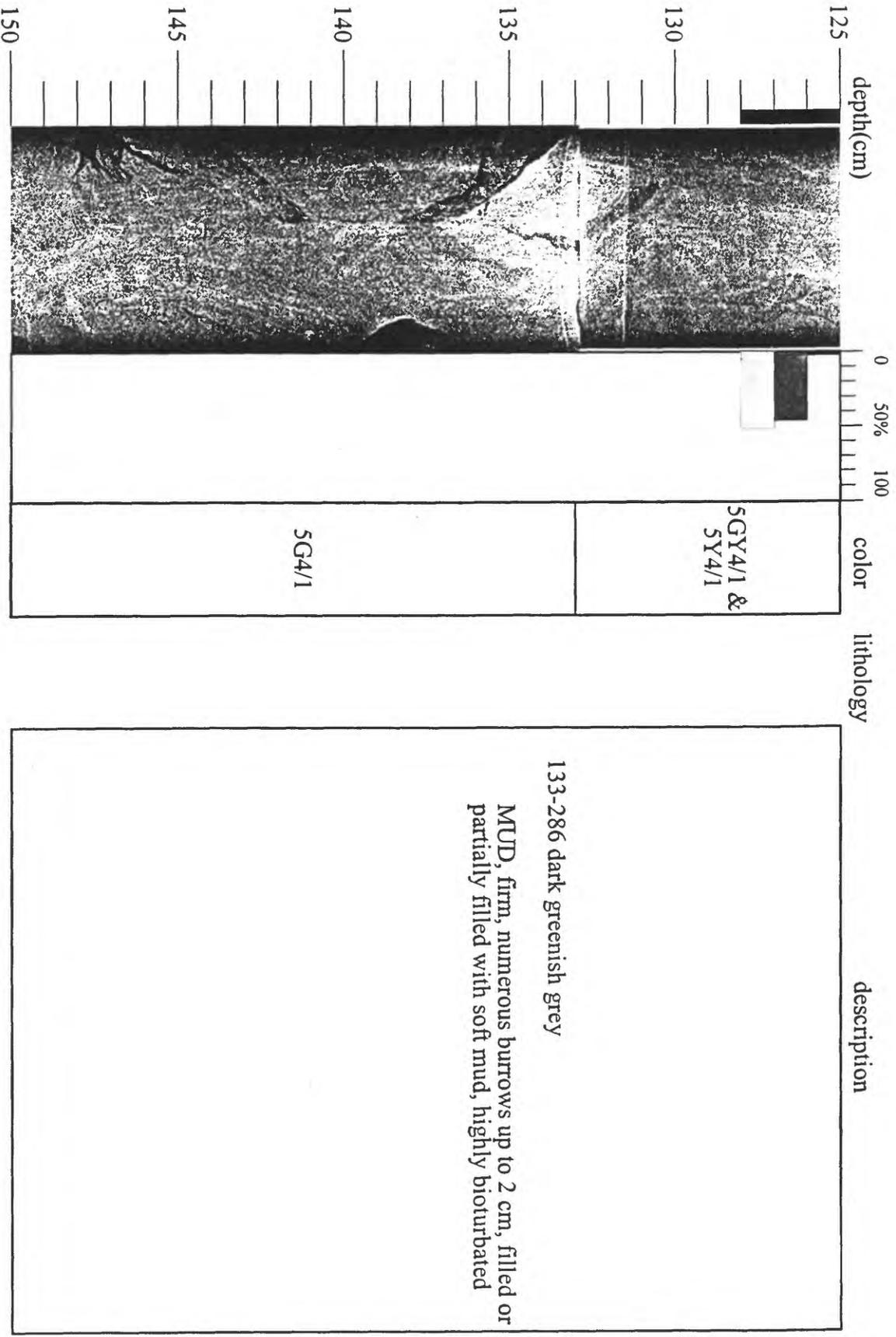
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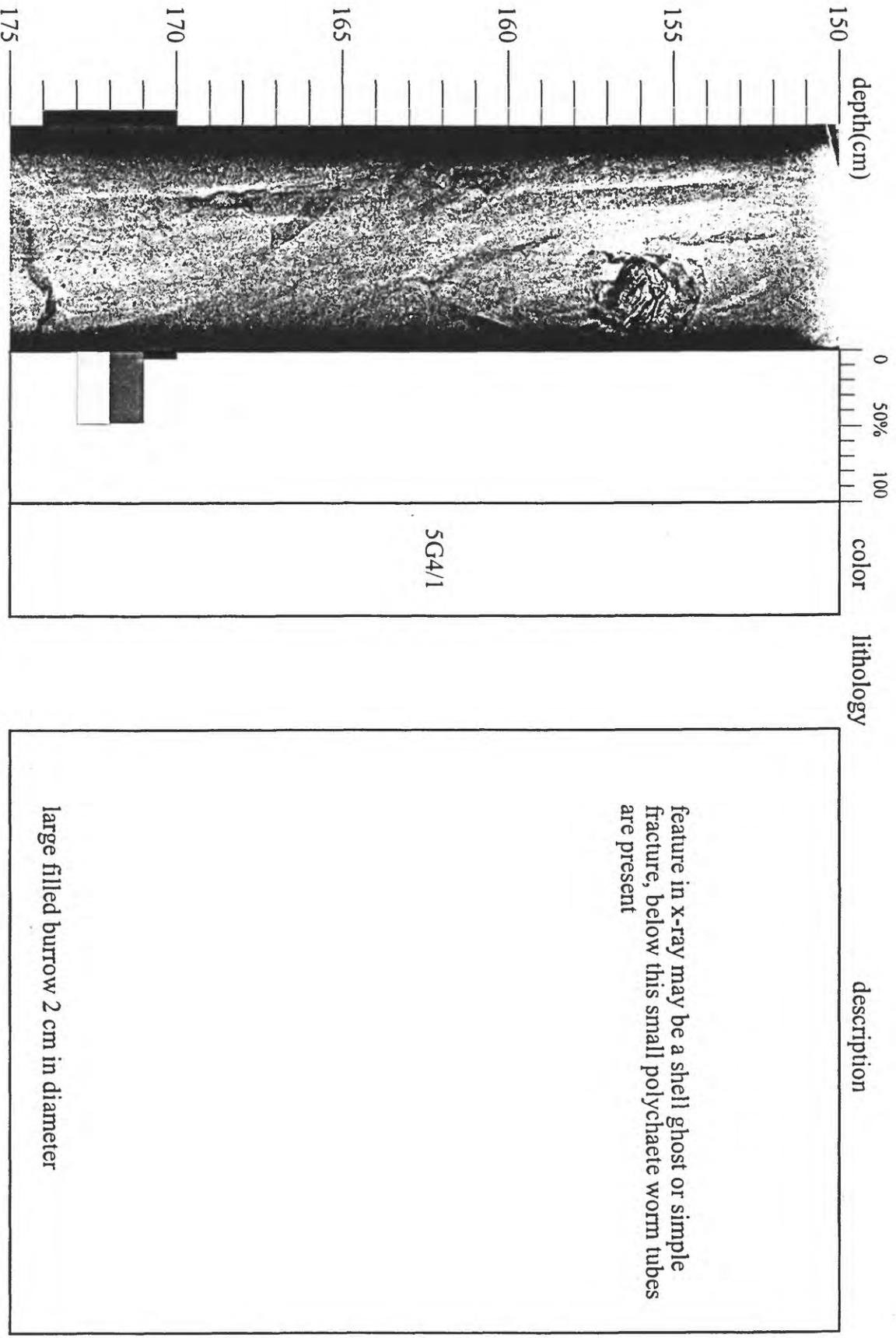
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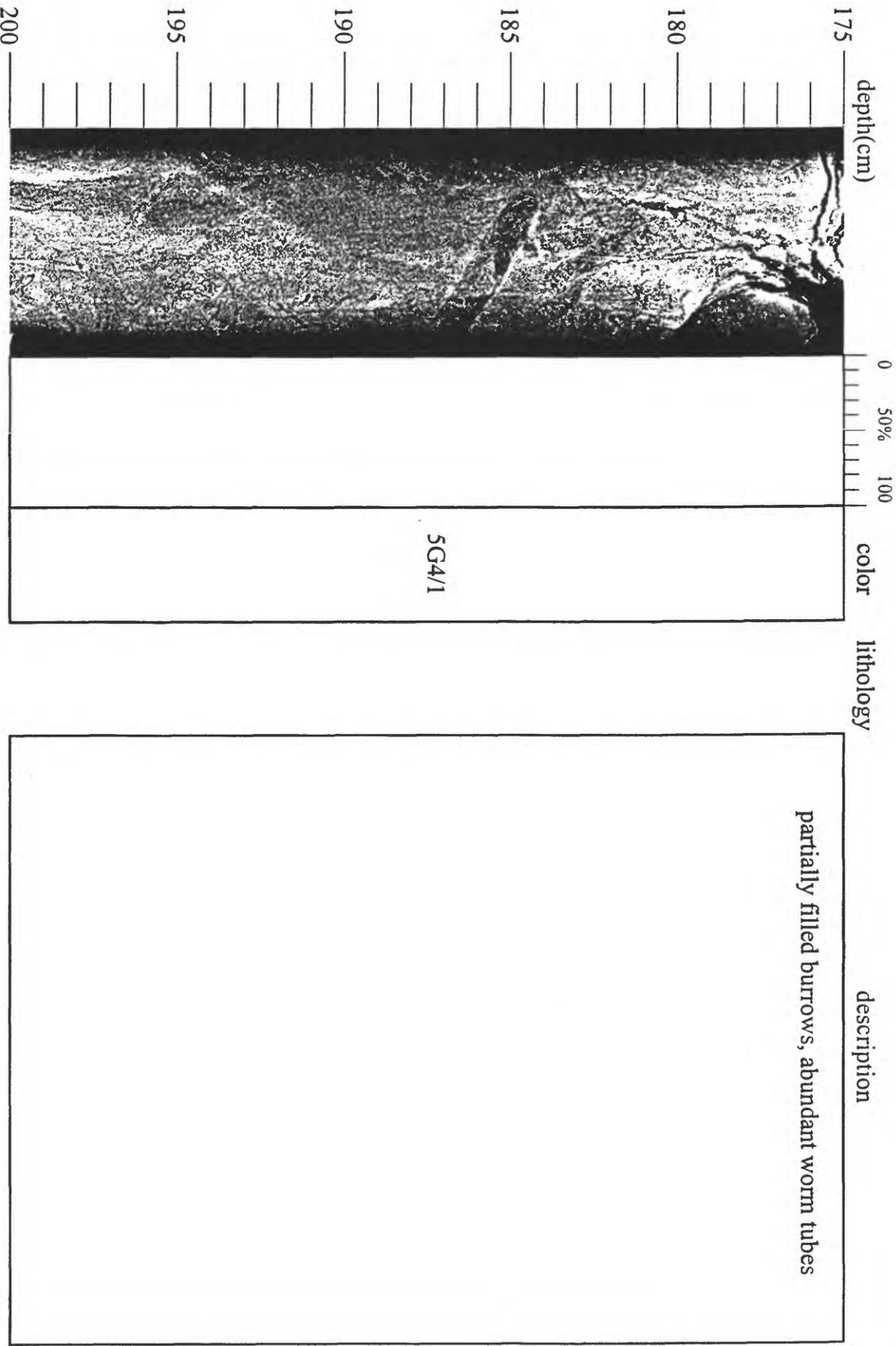
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5G4/1

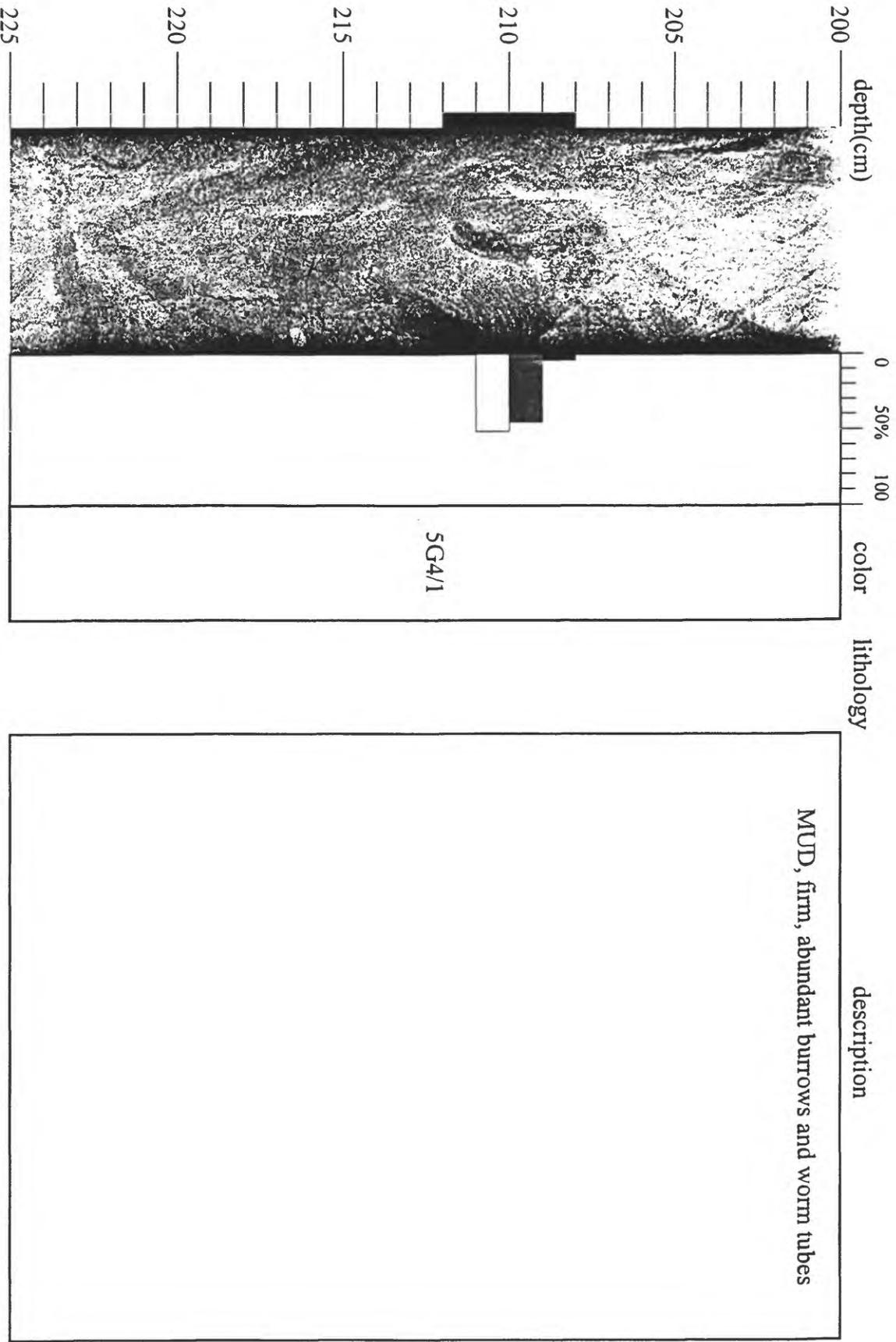
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Core PTXT 3-2

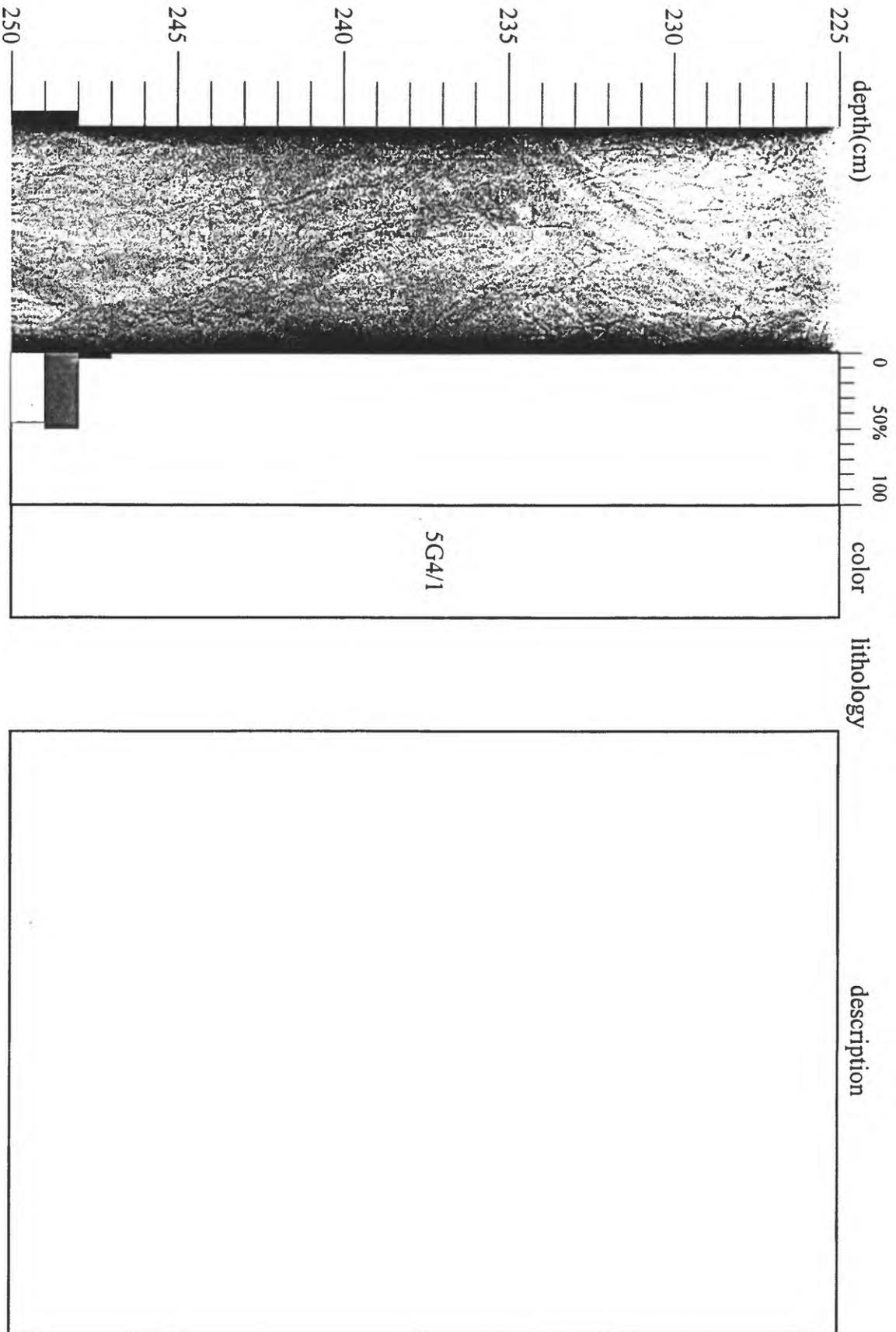


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Core PTXT 3-2

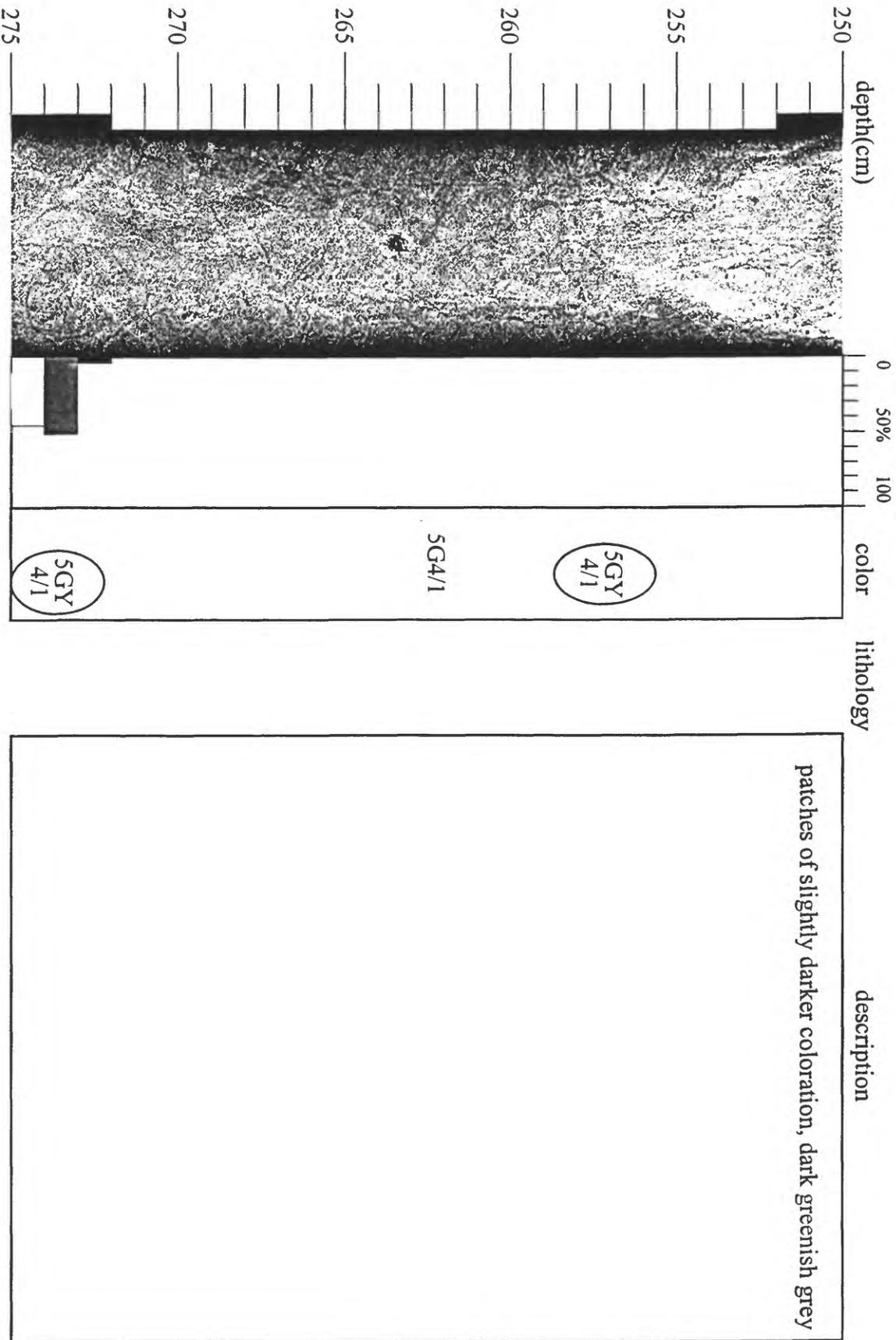


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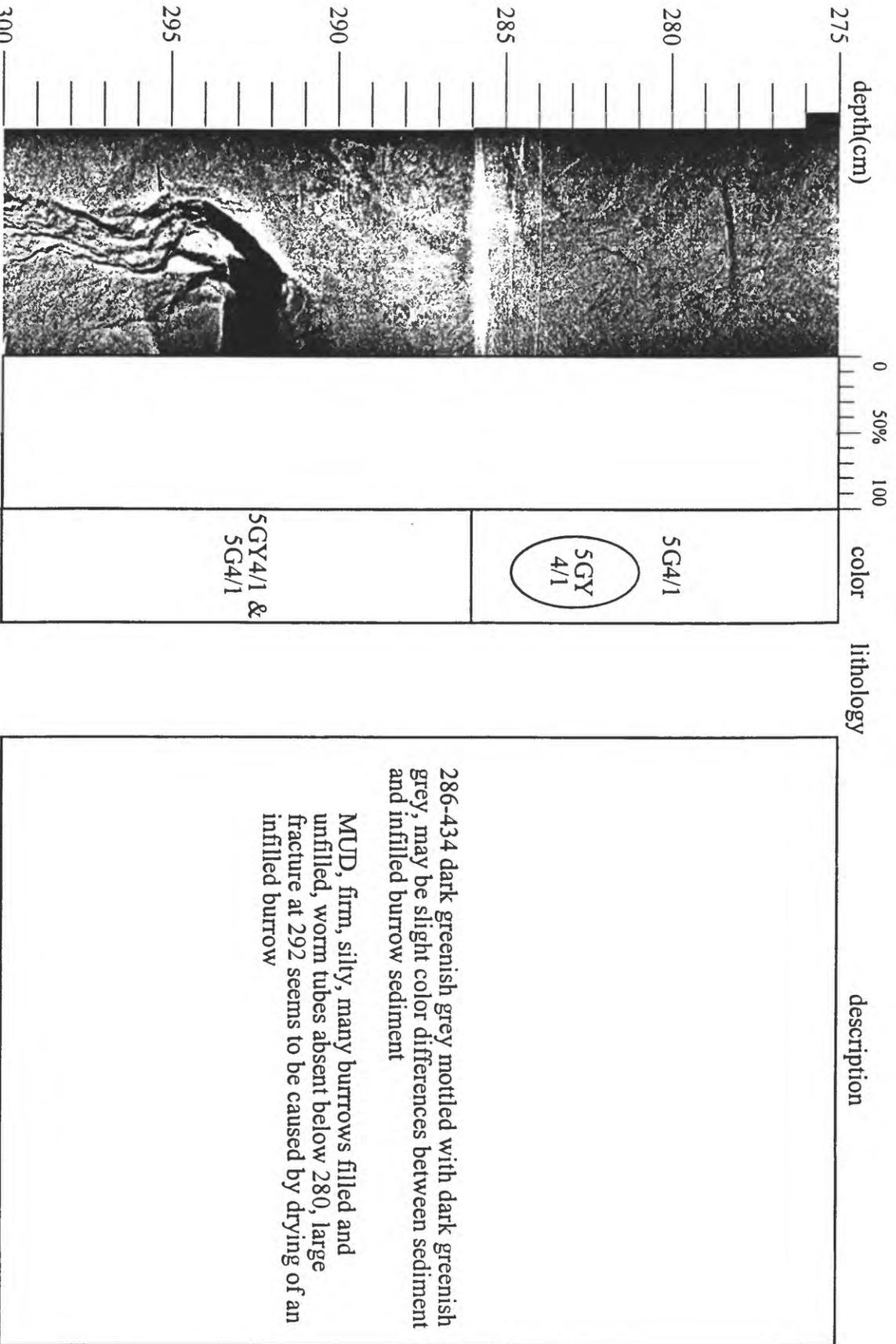
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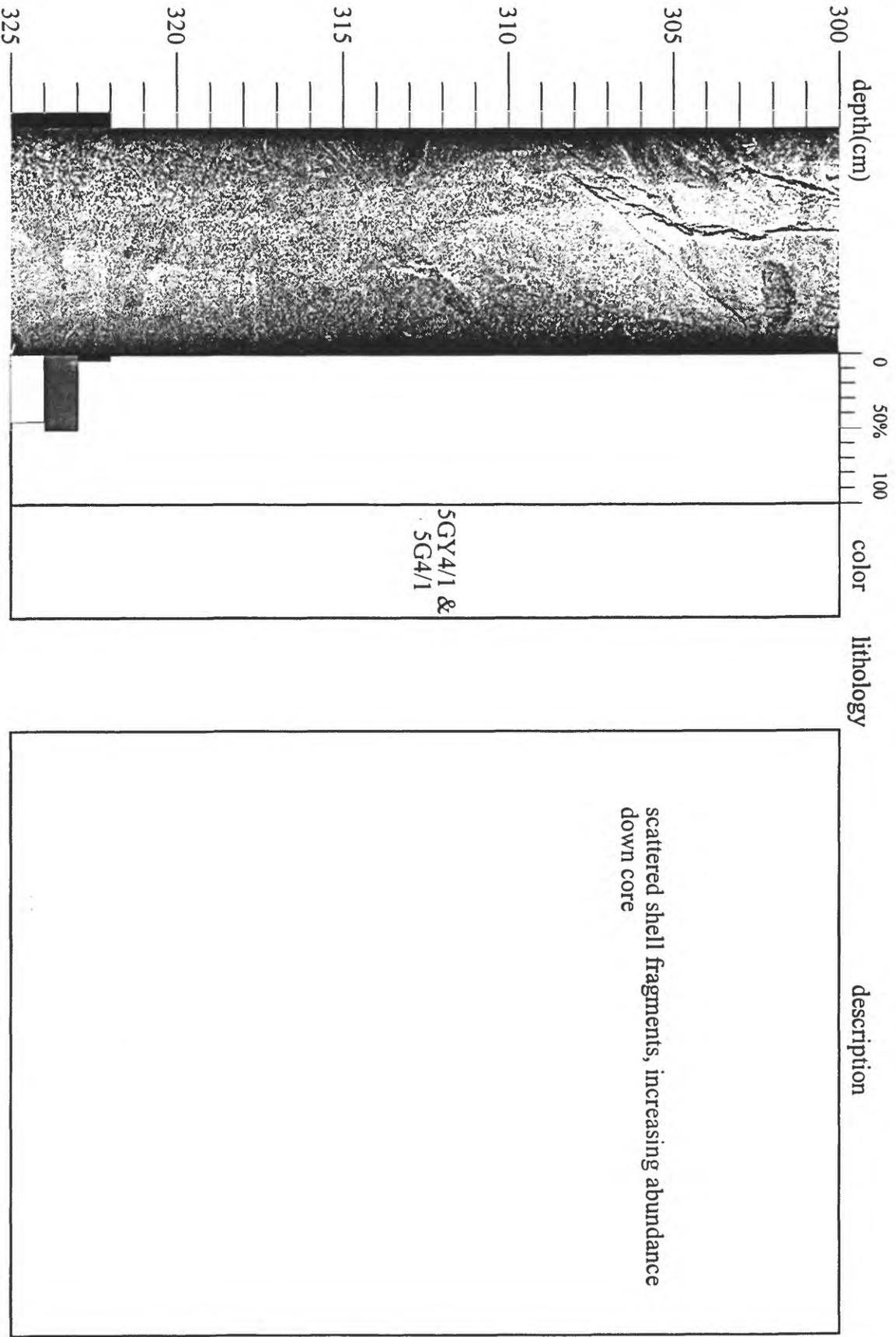
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Core PTXT 3-2



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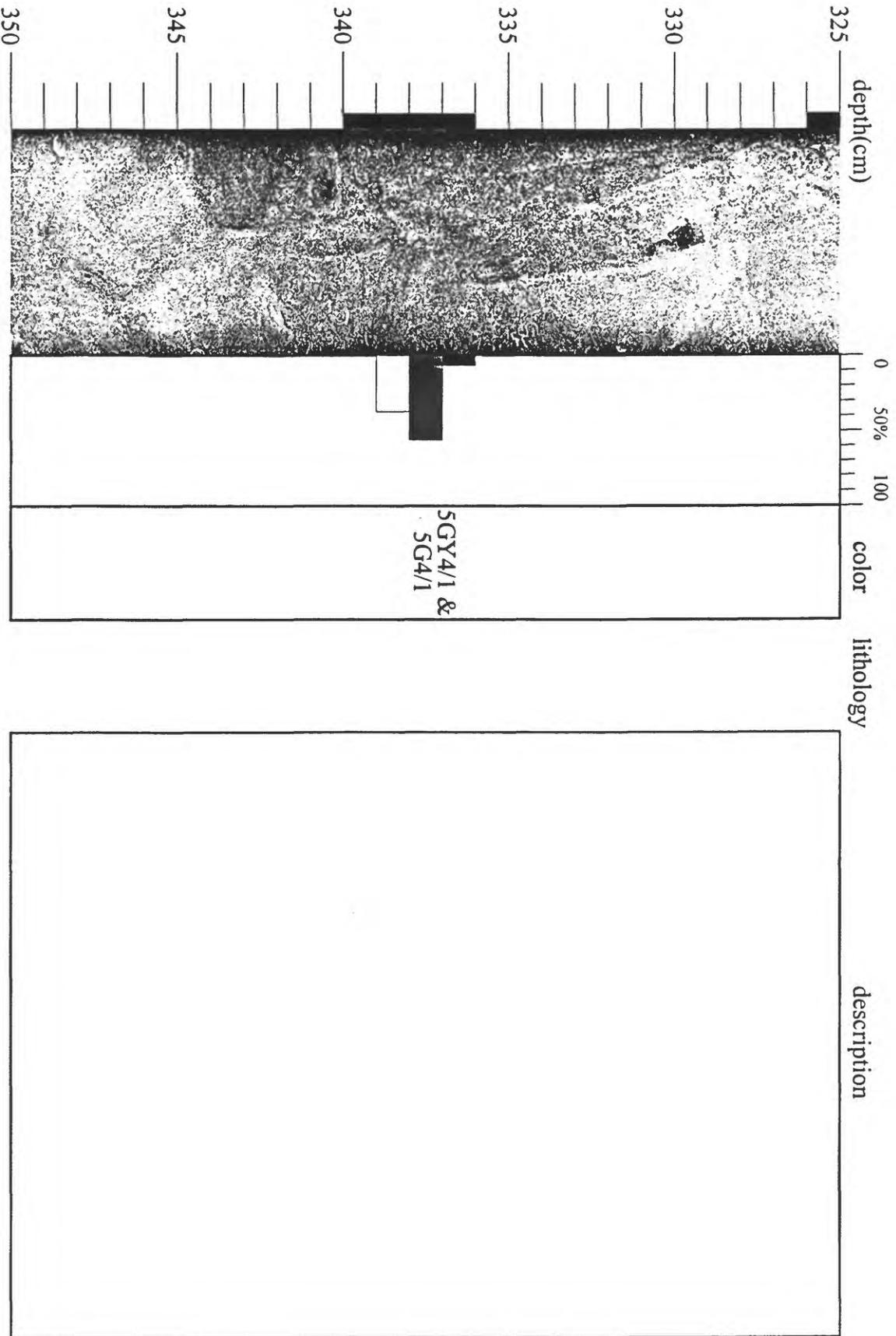
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SGY4/1 &
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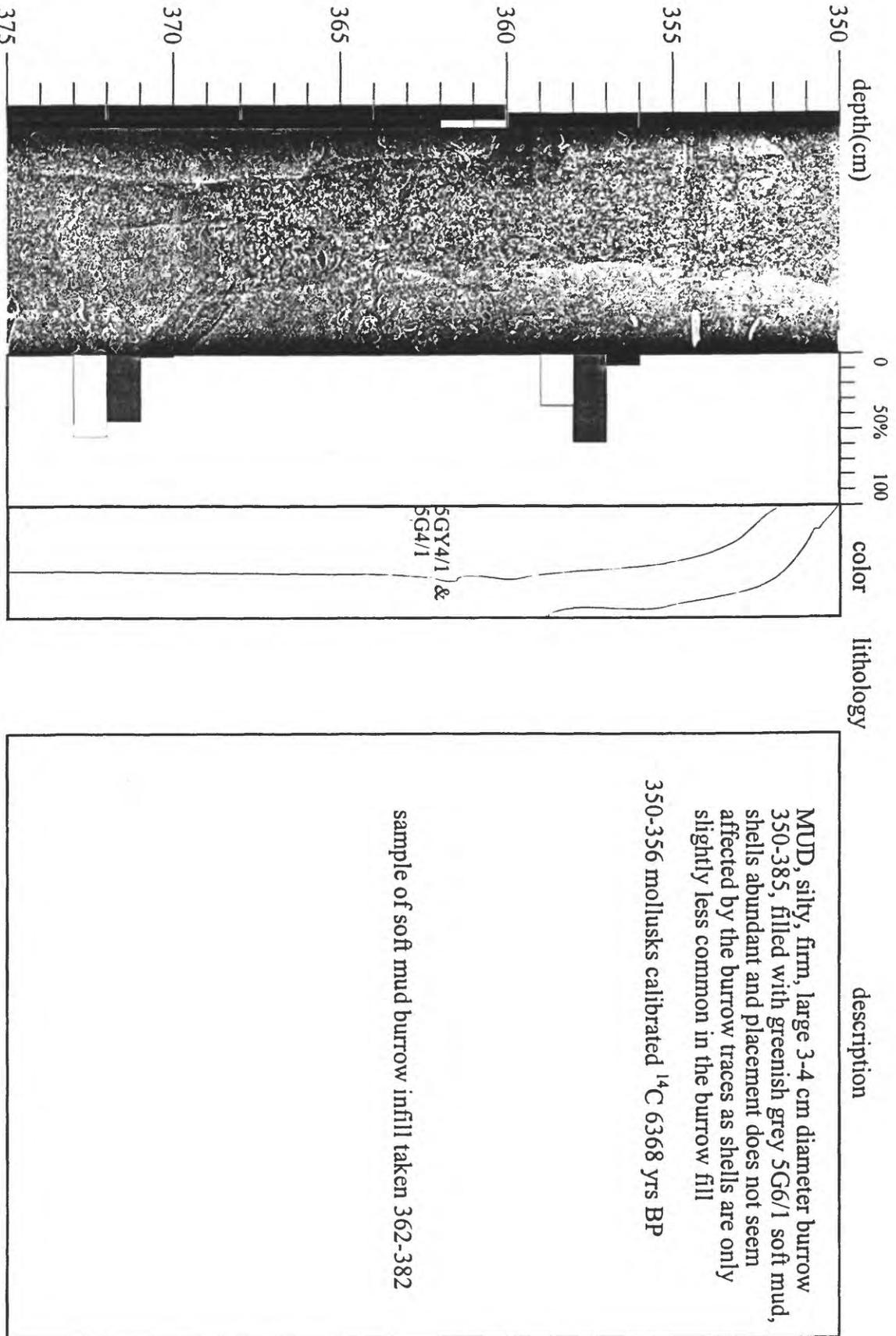
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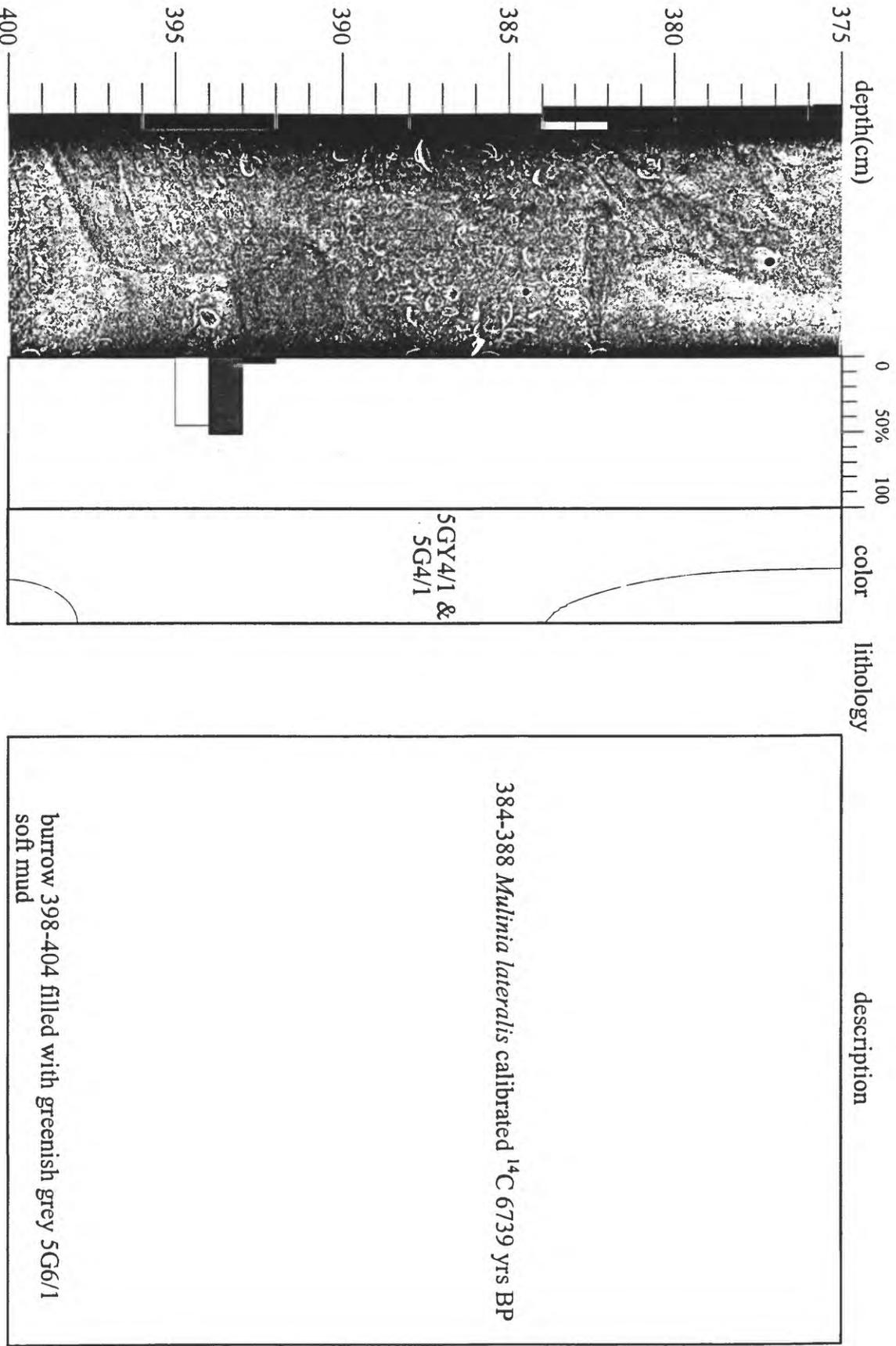
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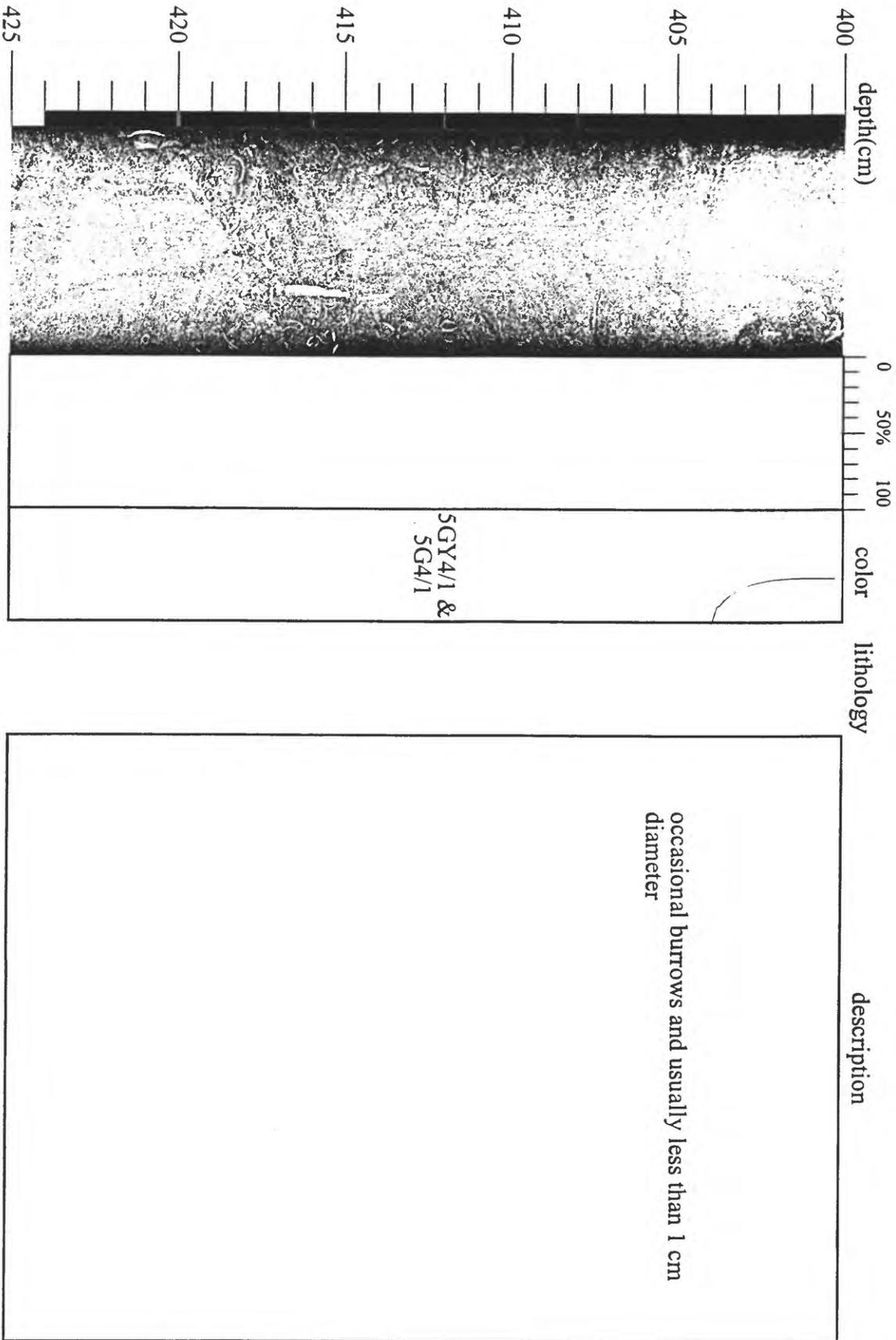
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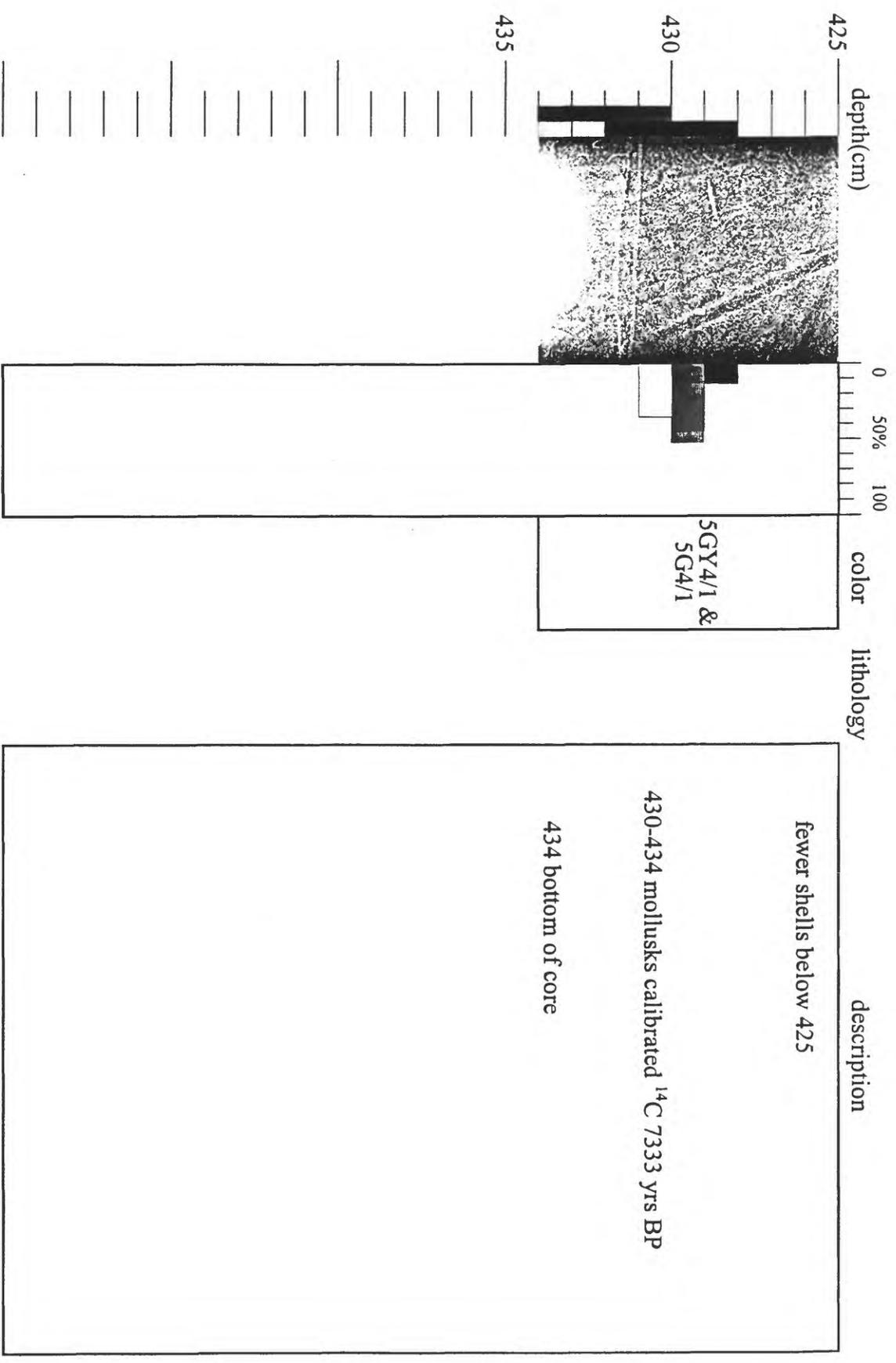
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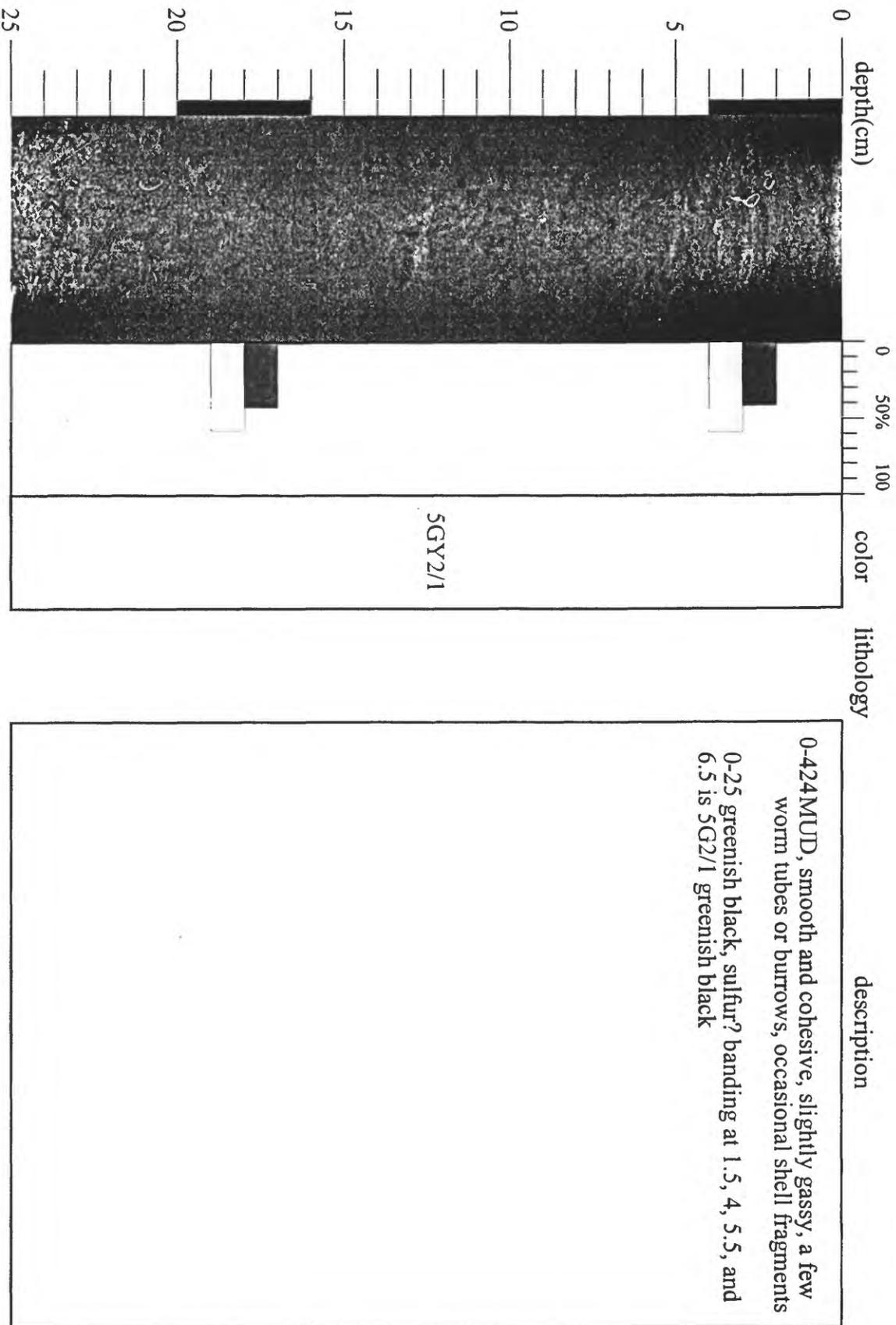
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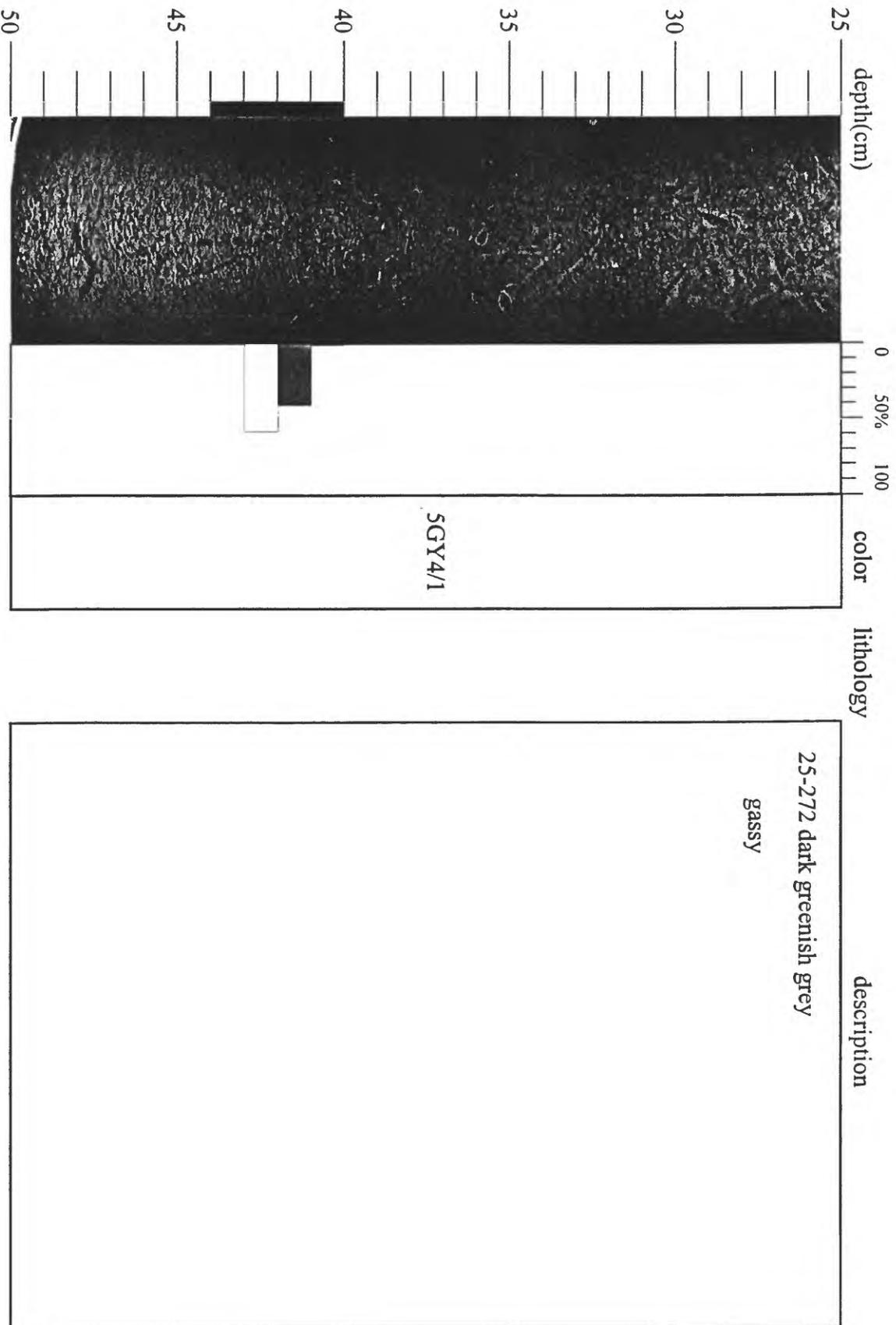
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Core PTMC 1-2



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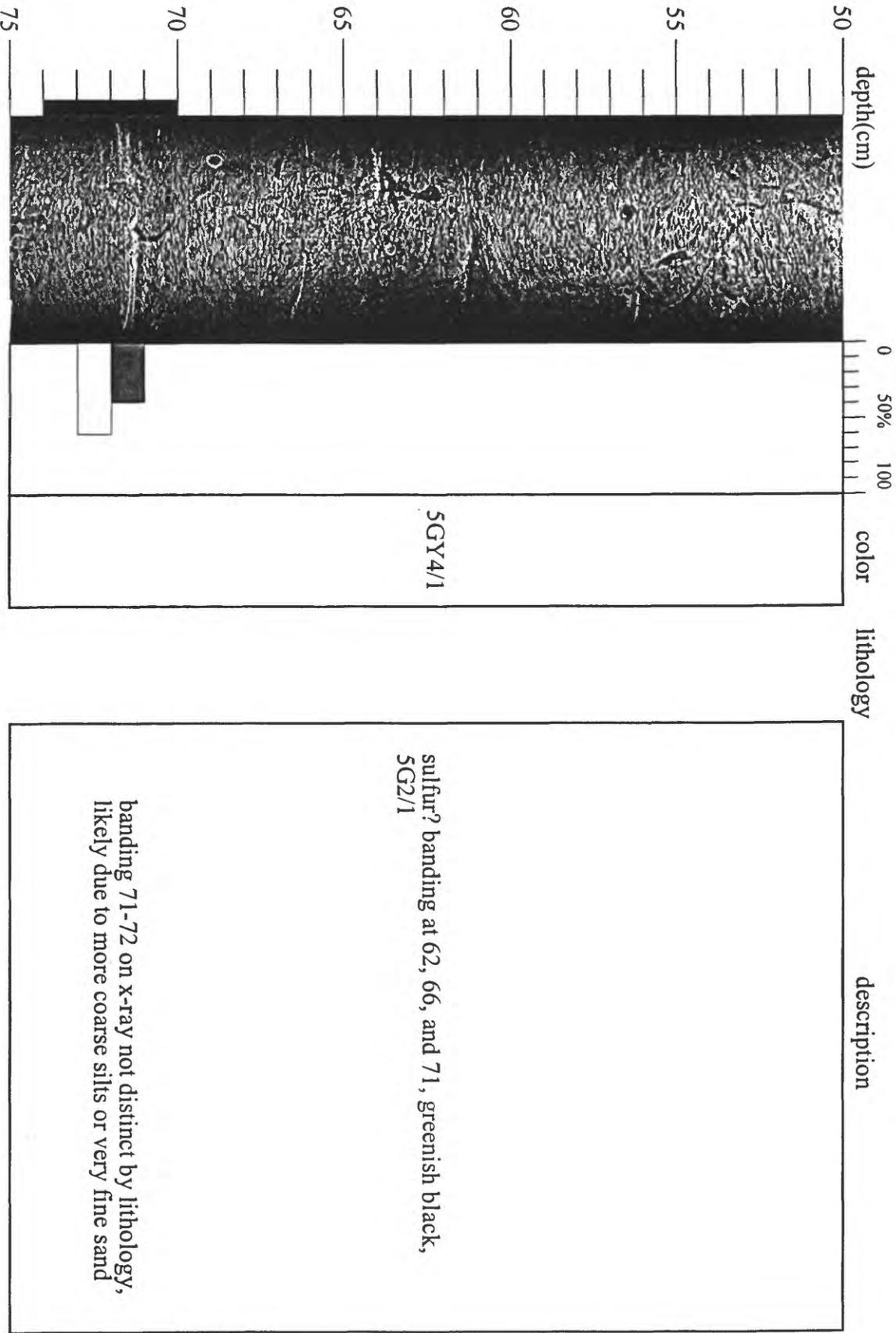
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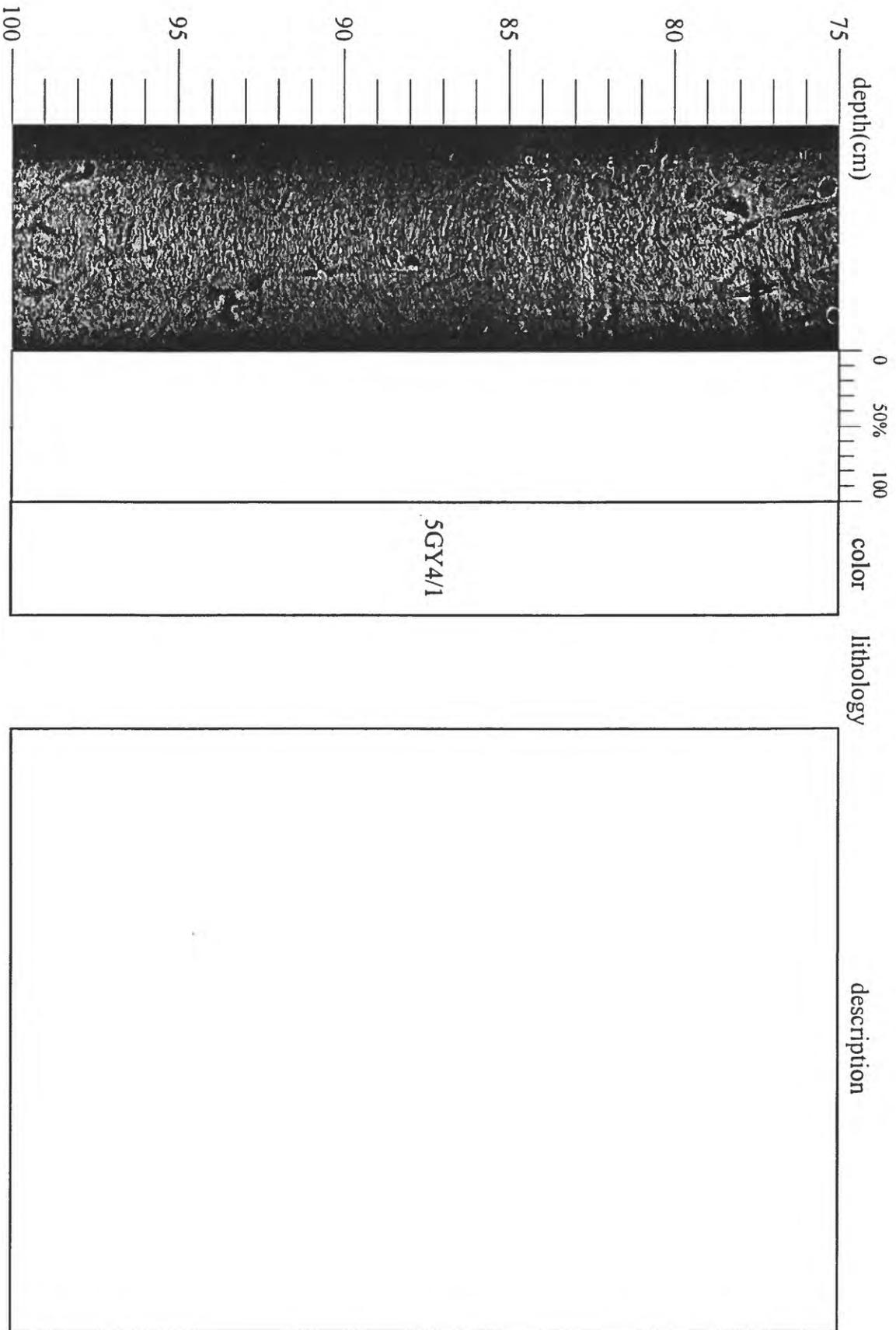
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Core PTMC 1-2



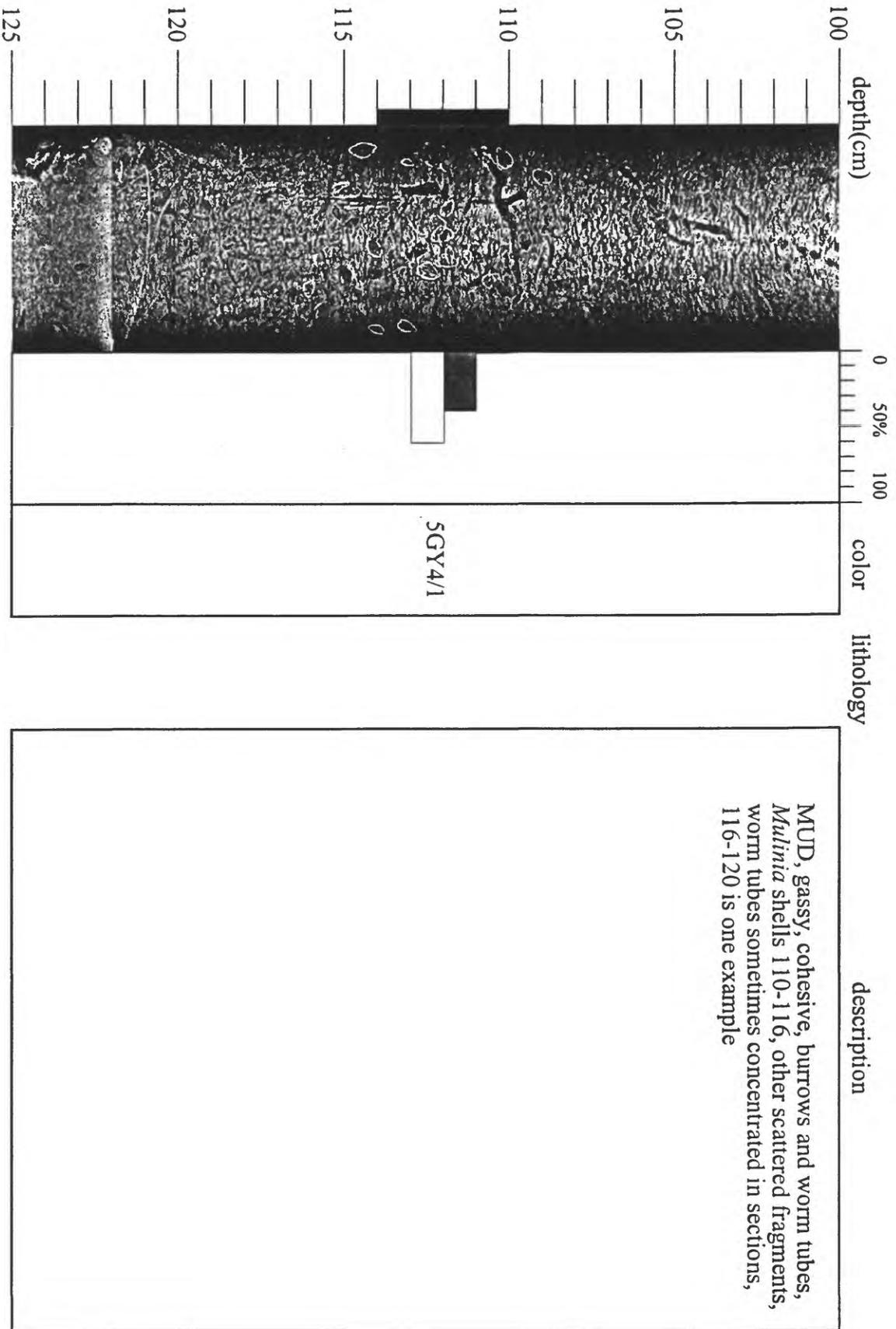
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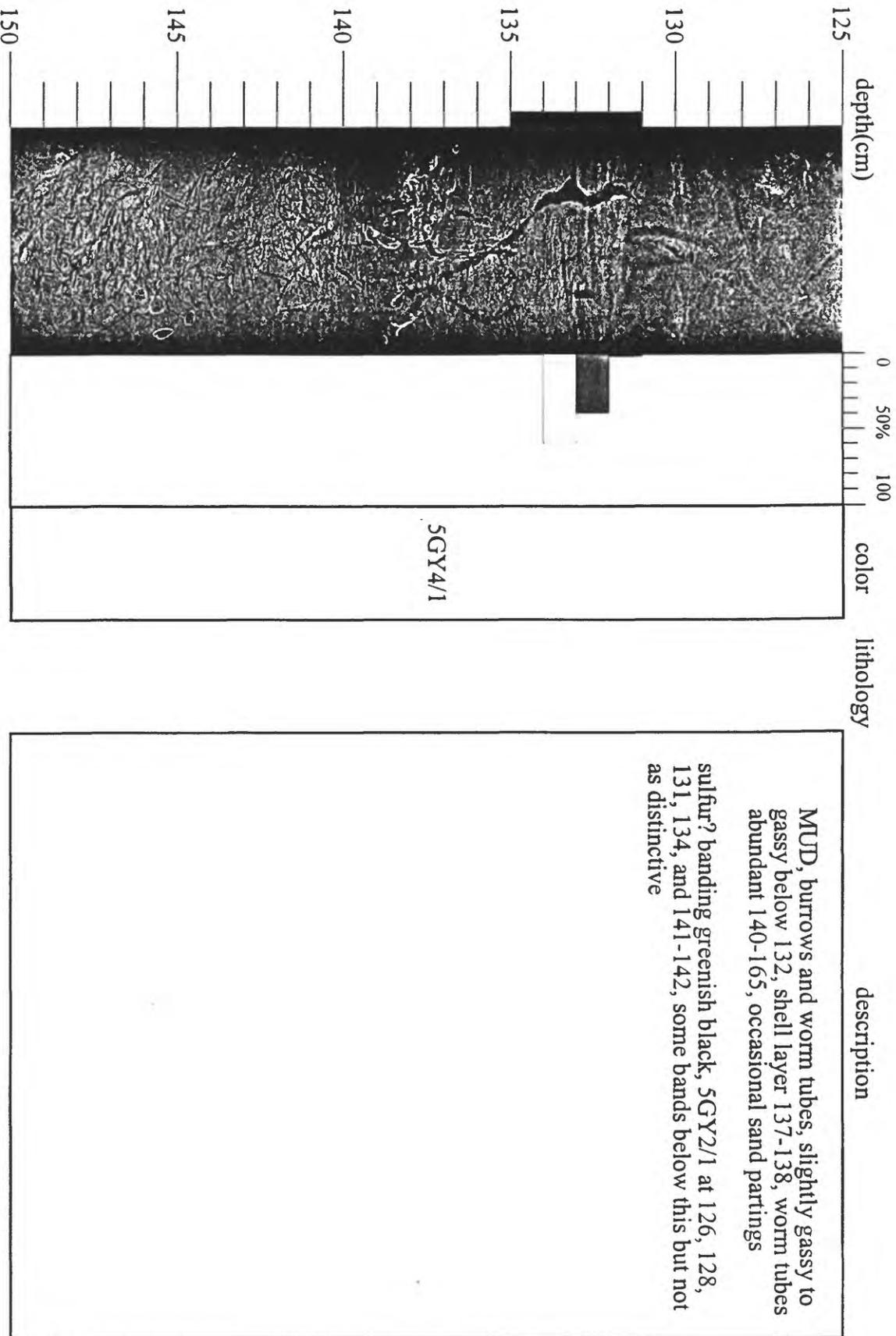
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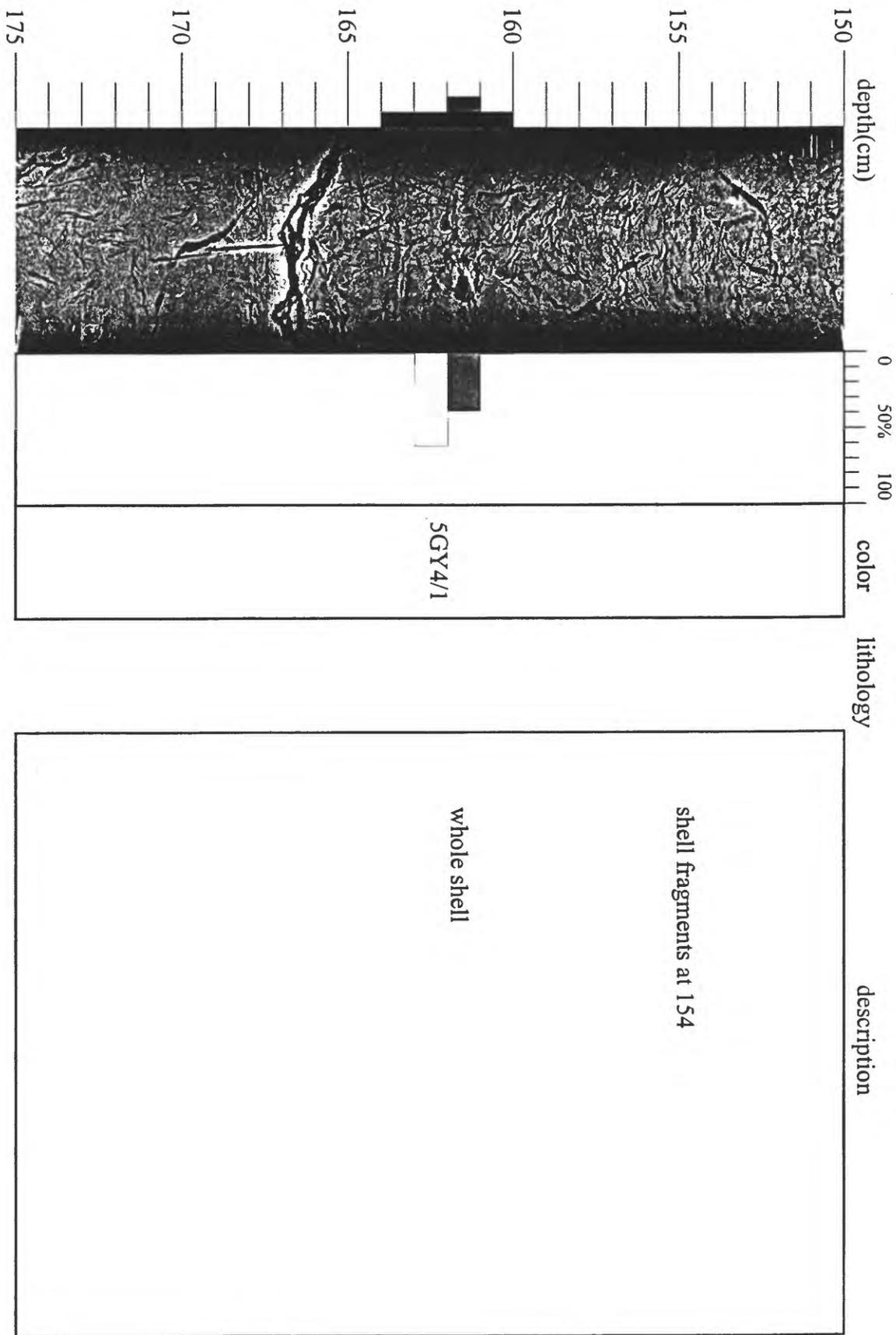
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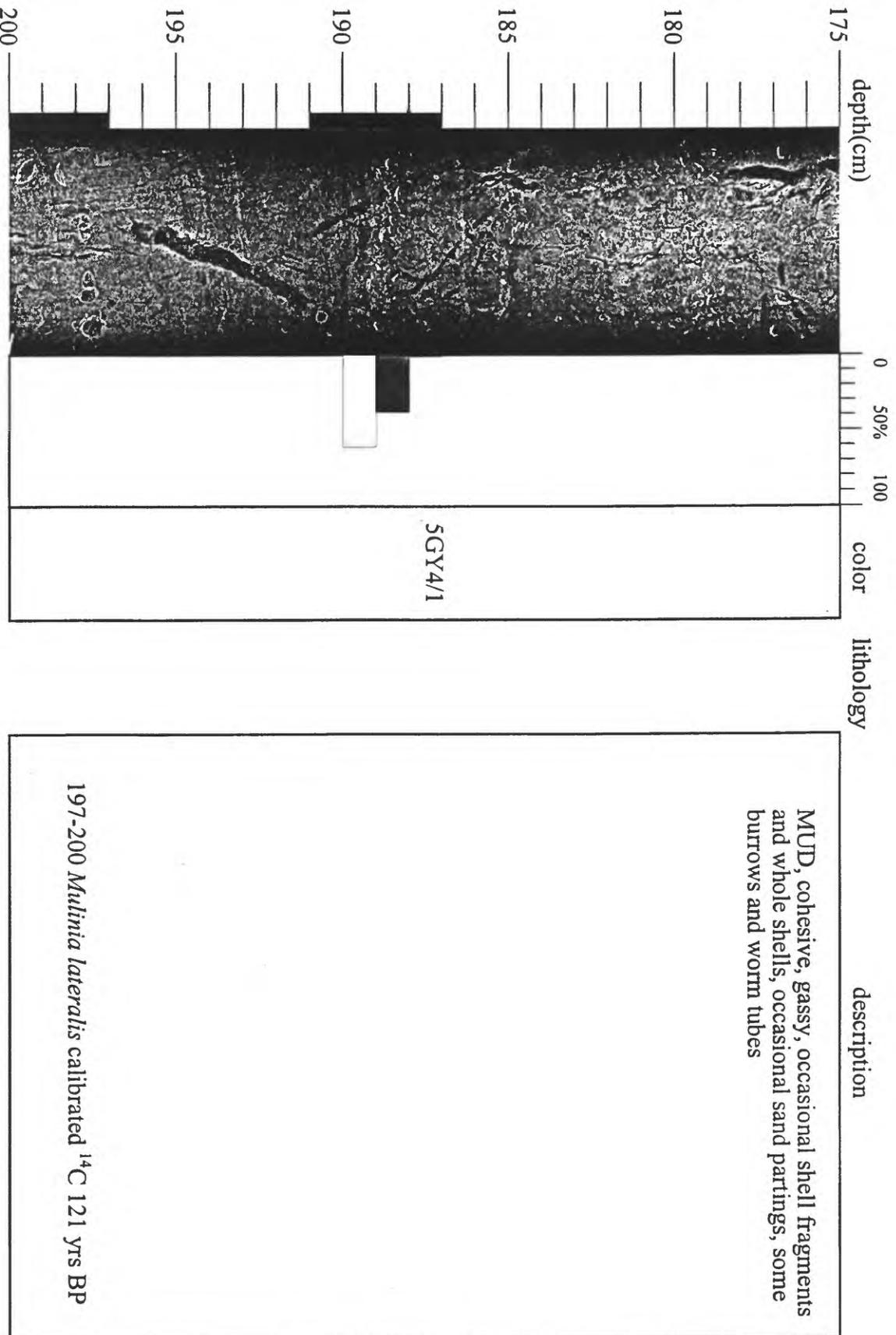
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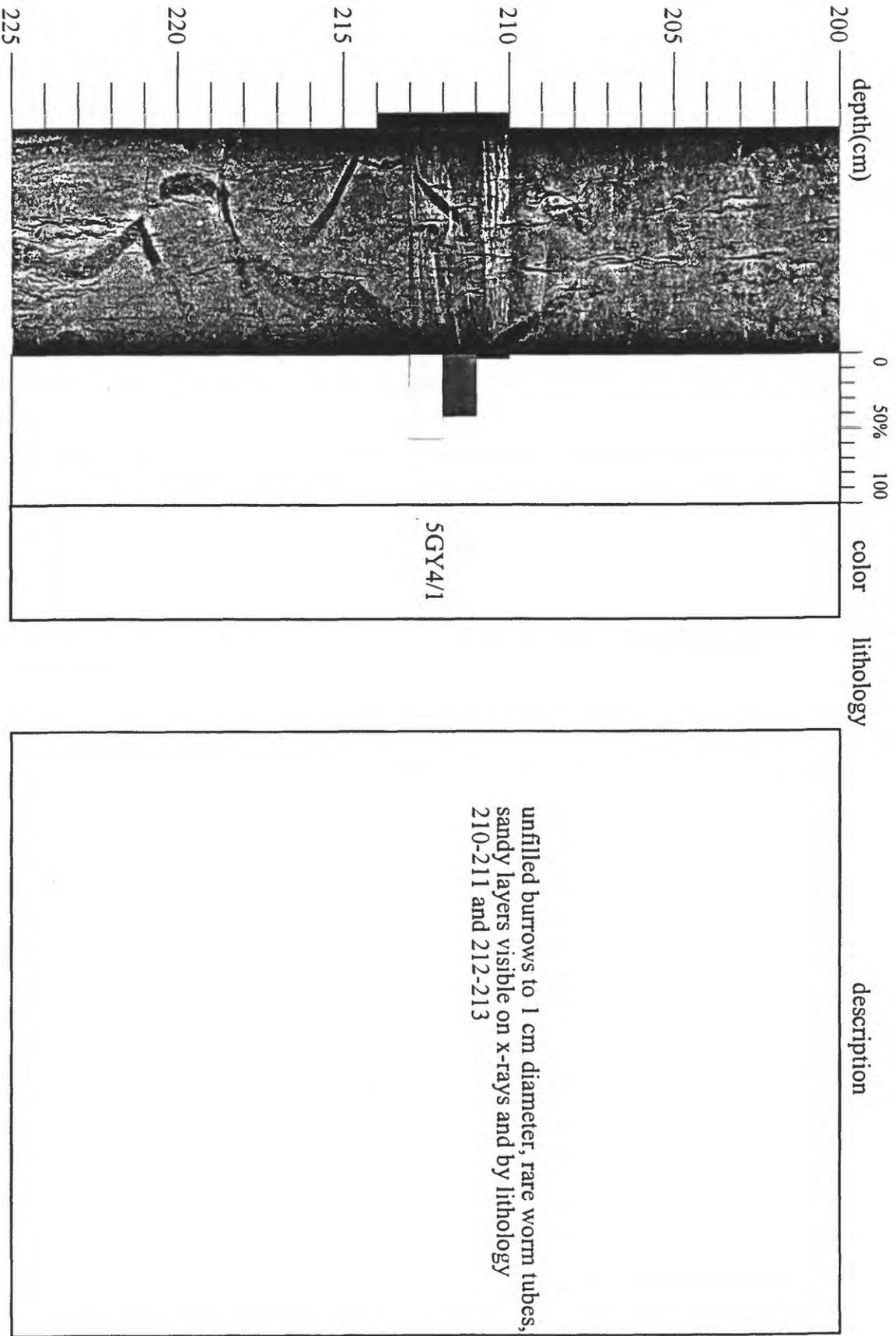
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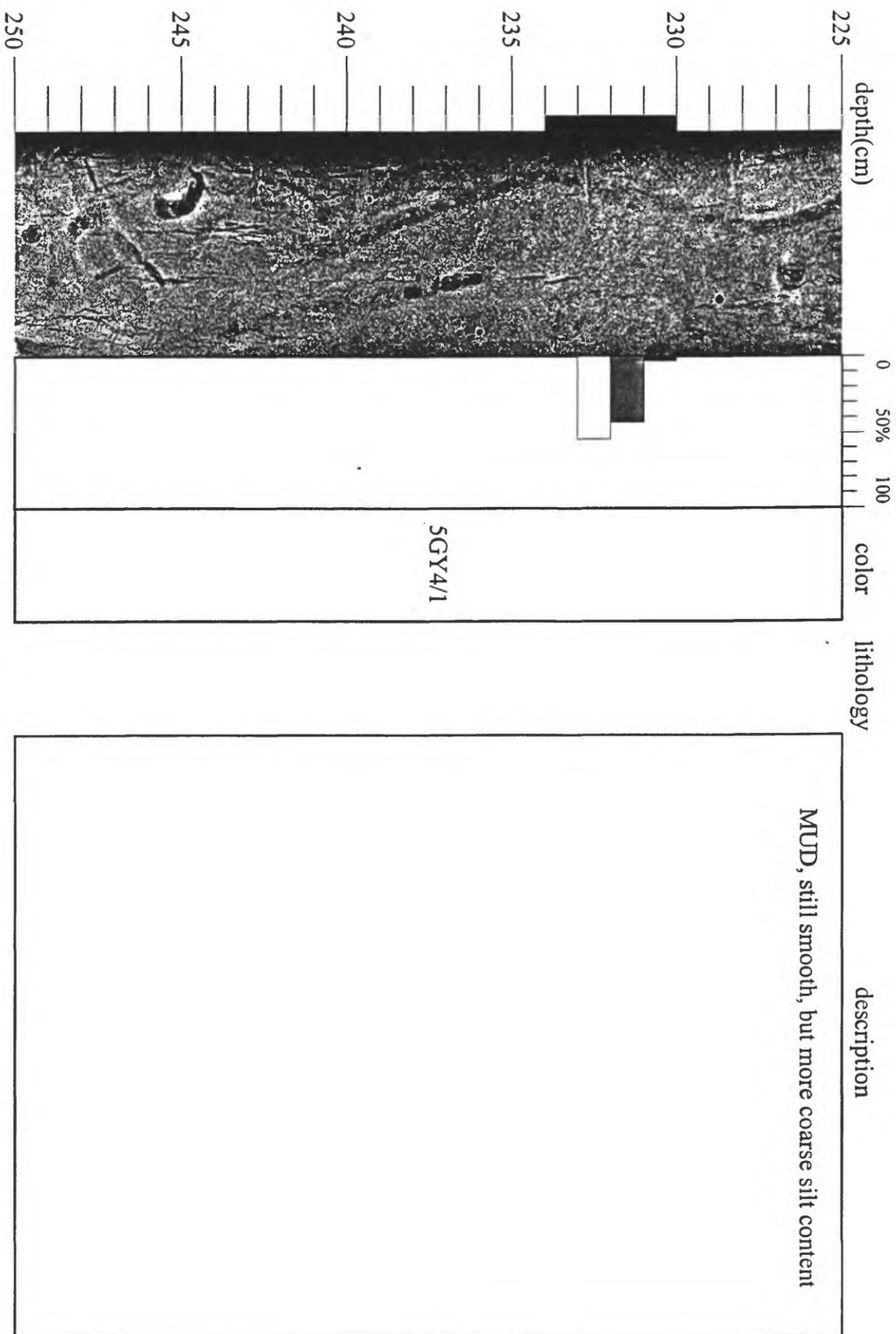
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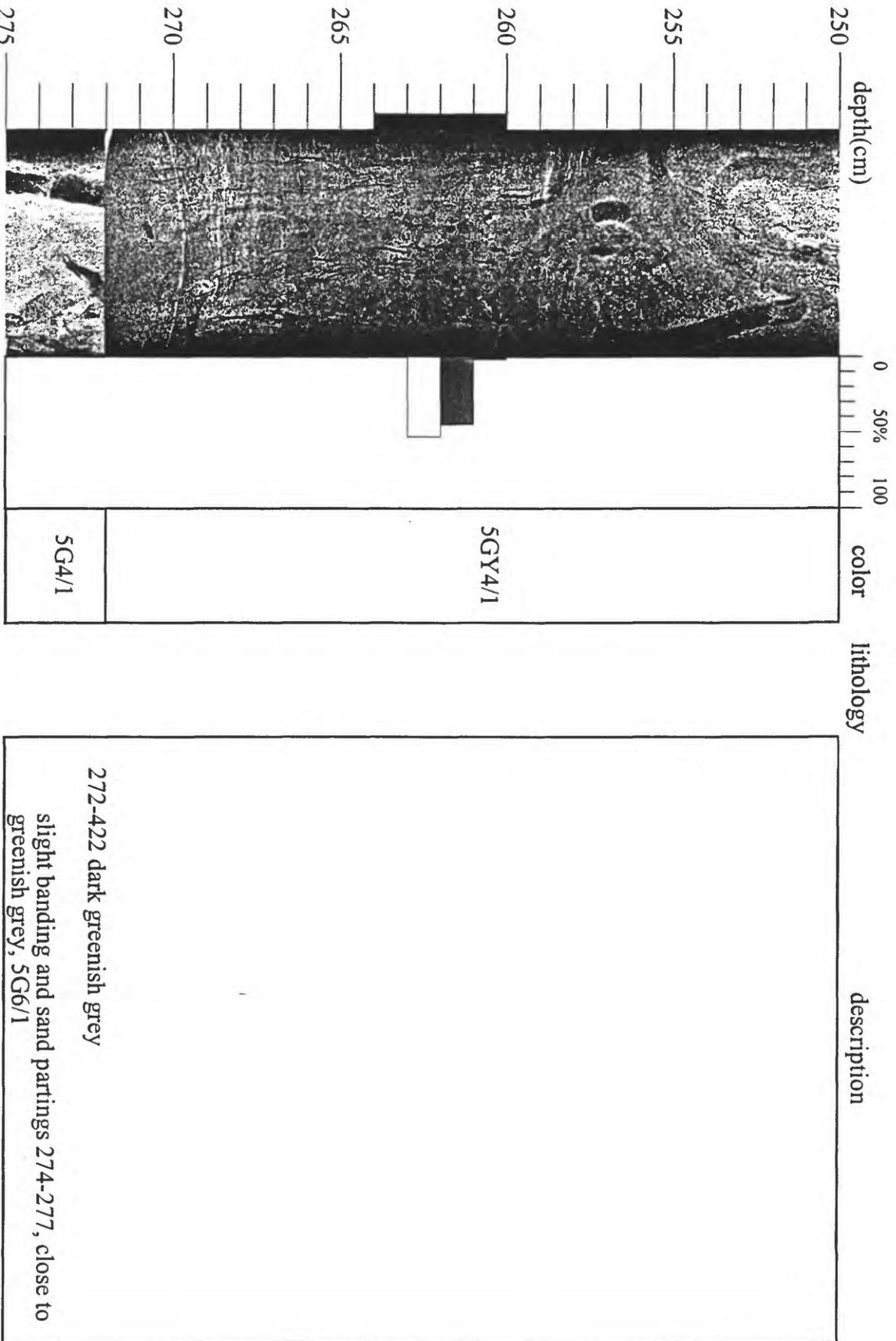
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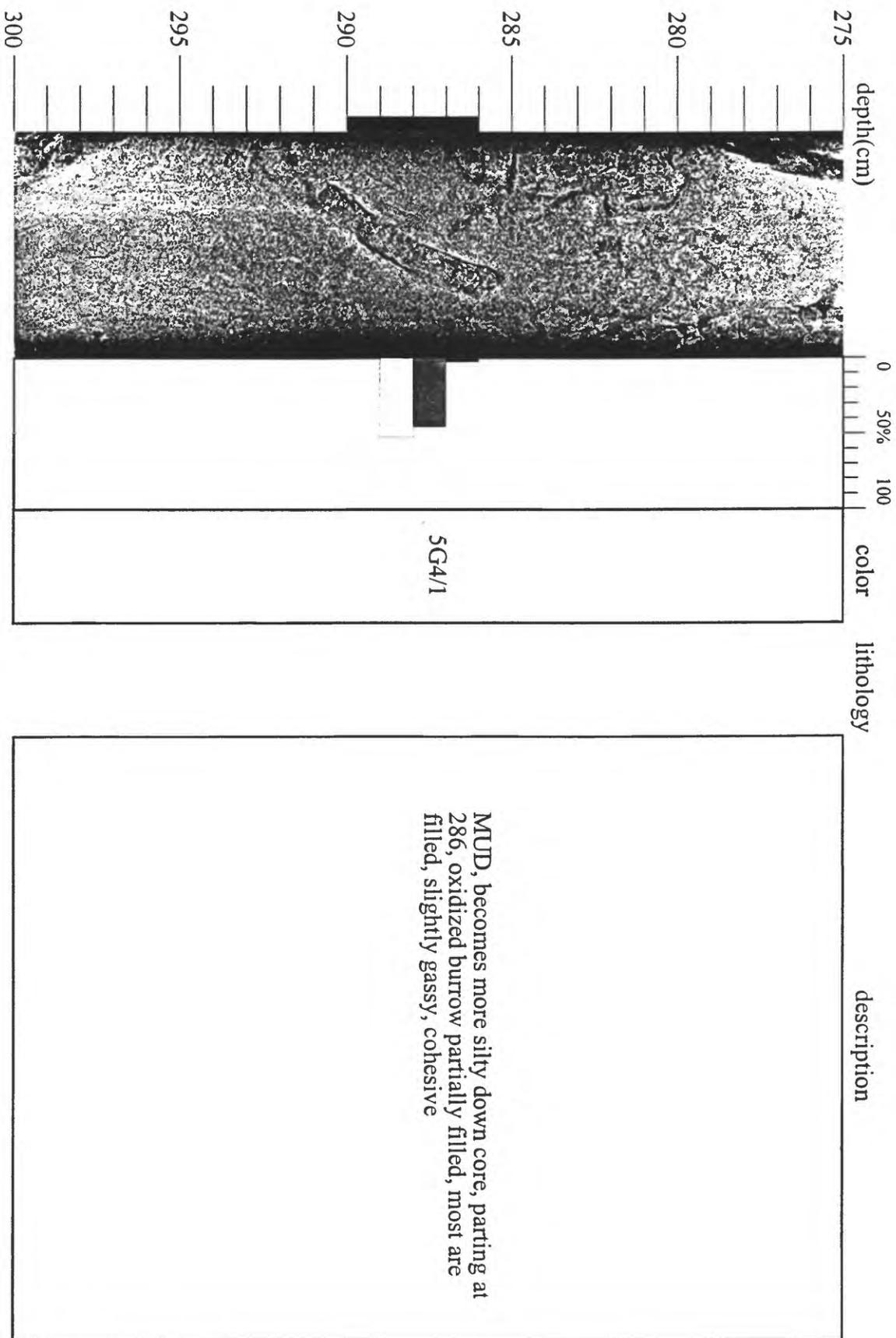
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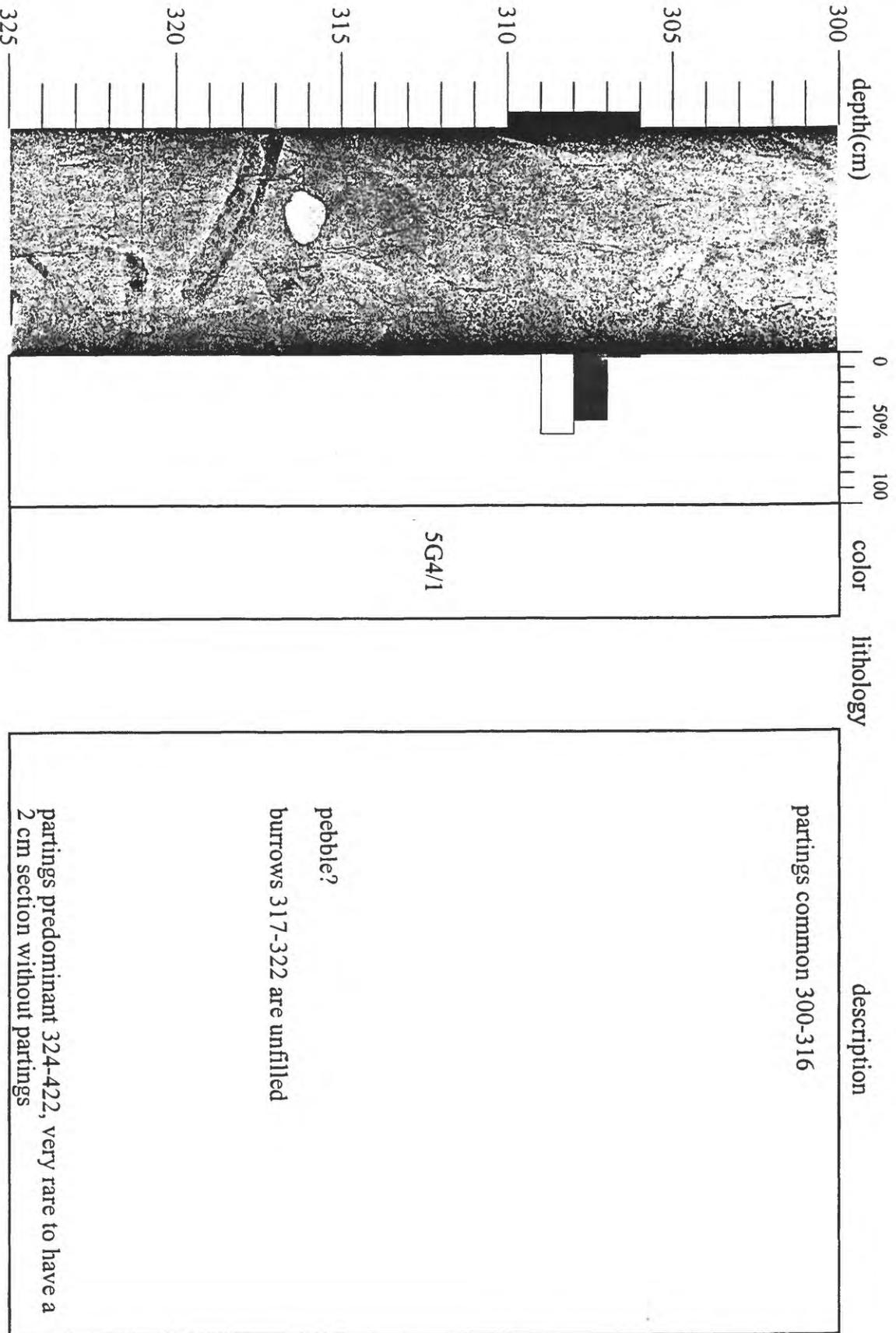
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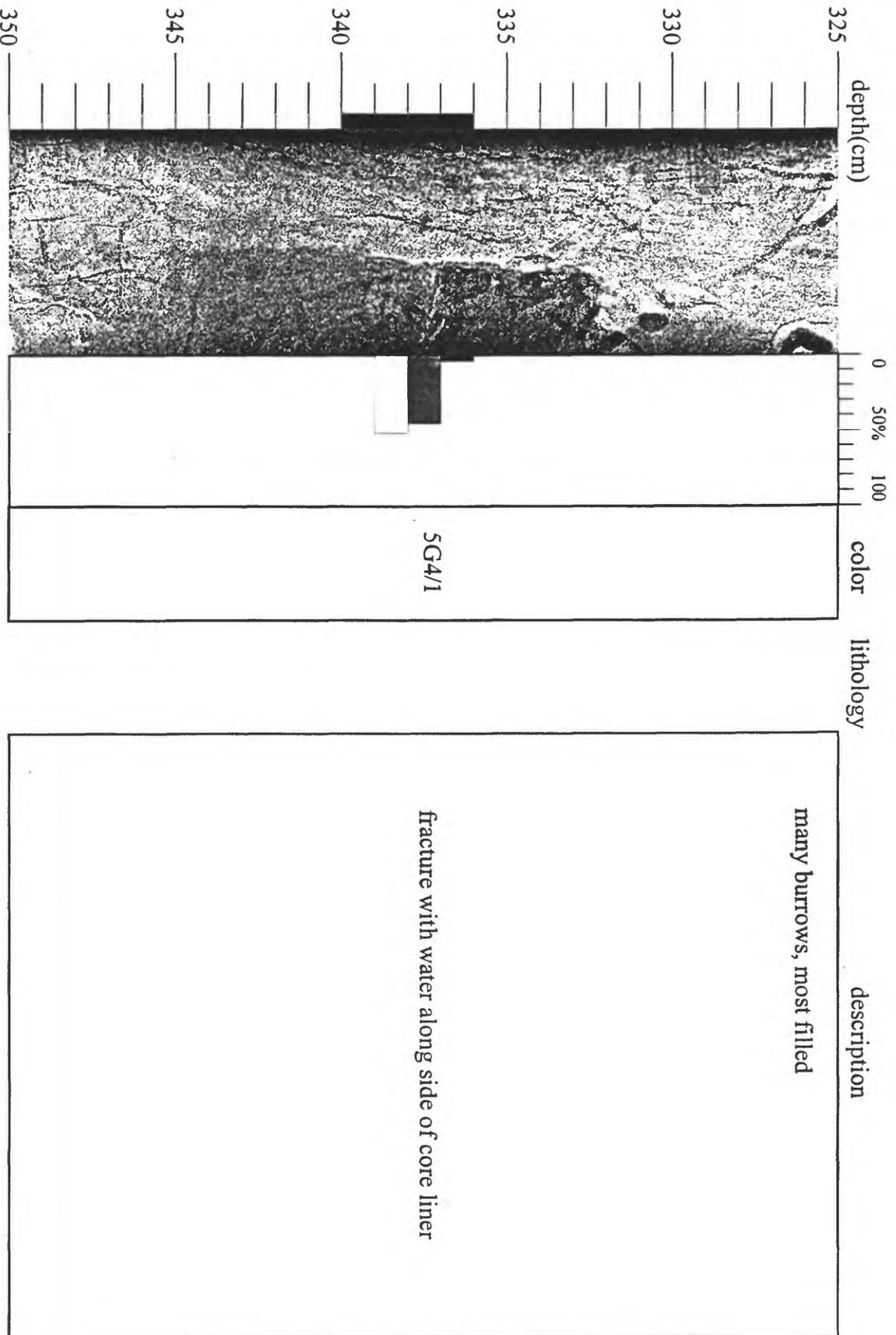
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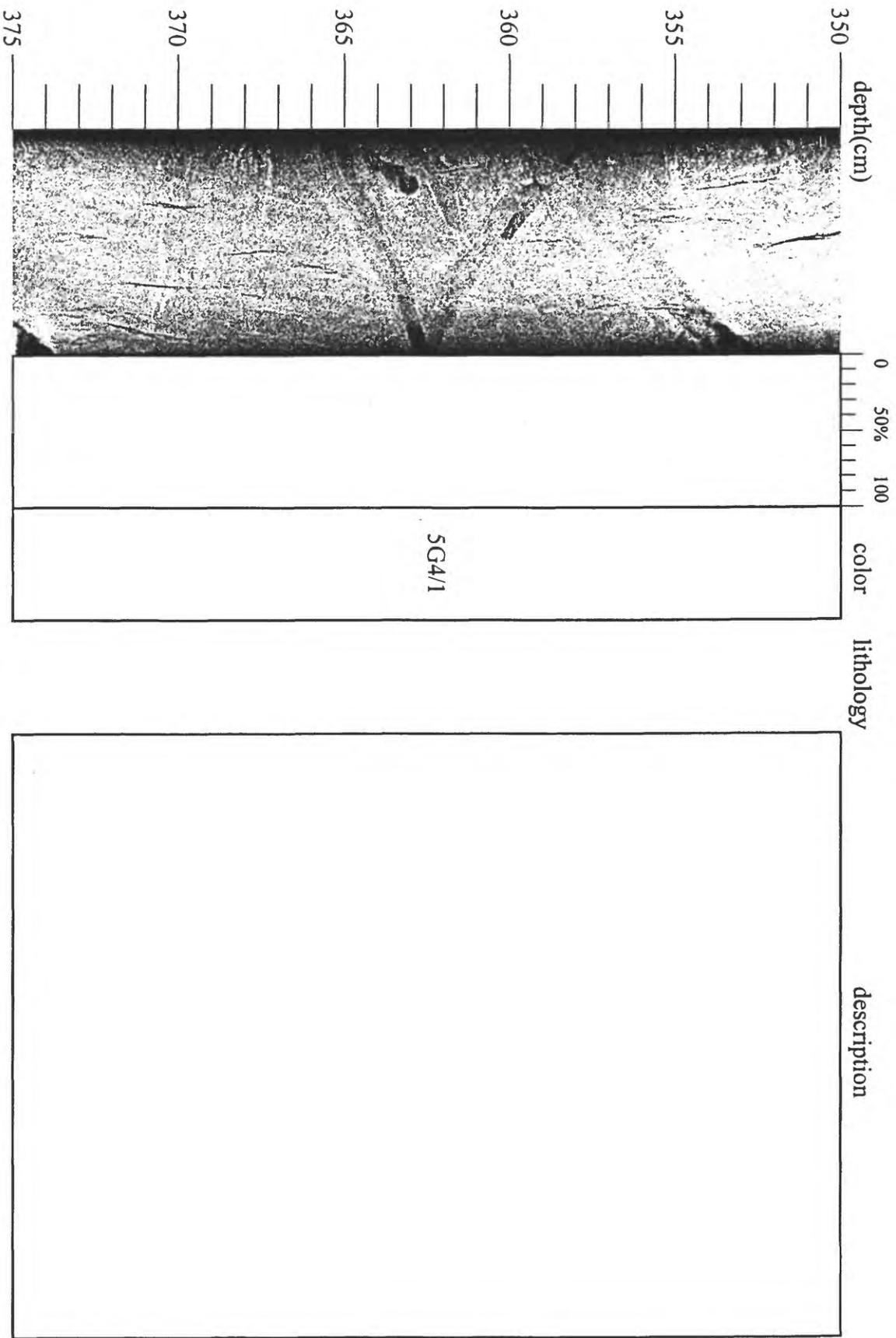
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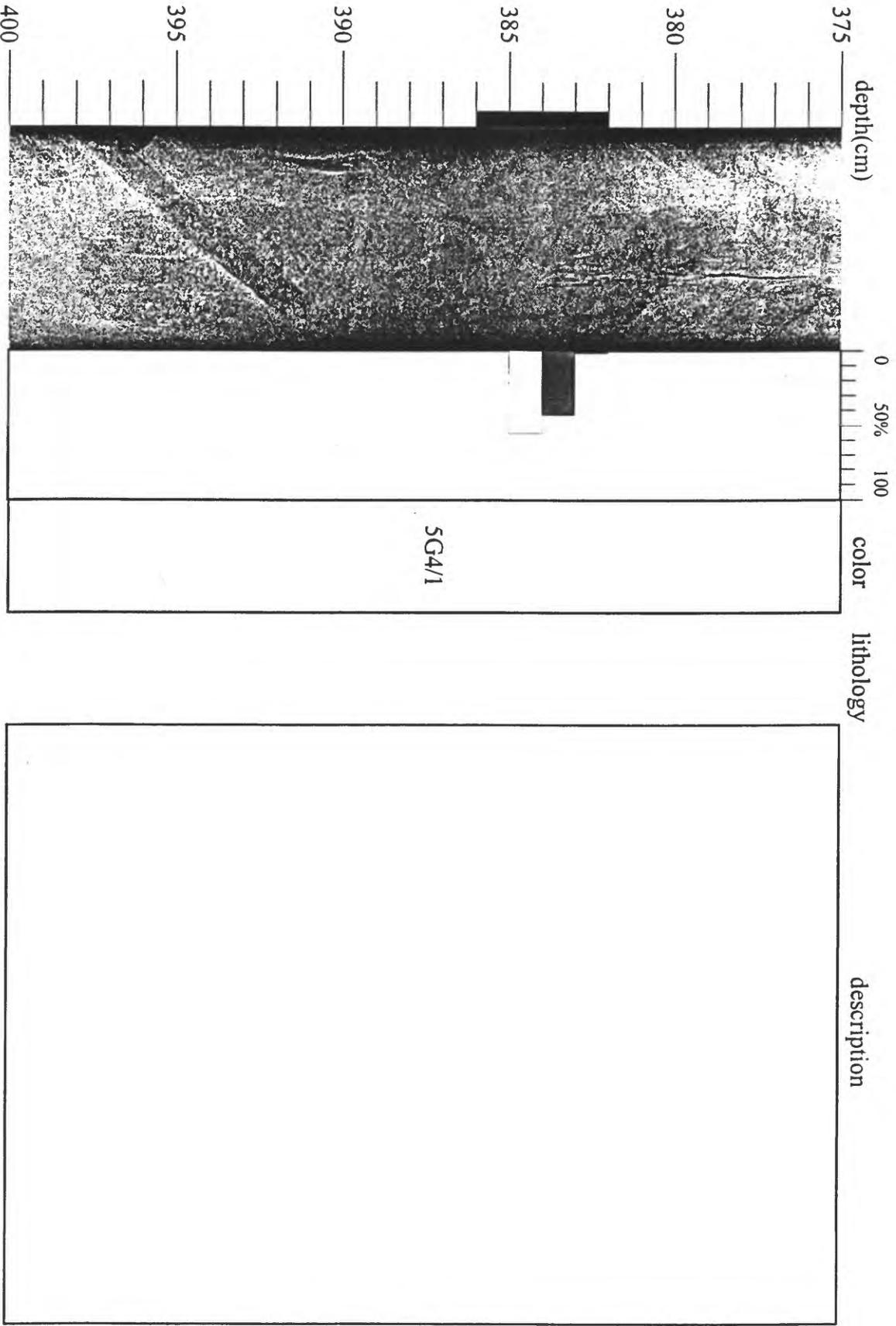
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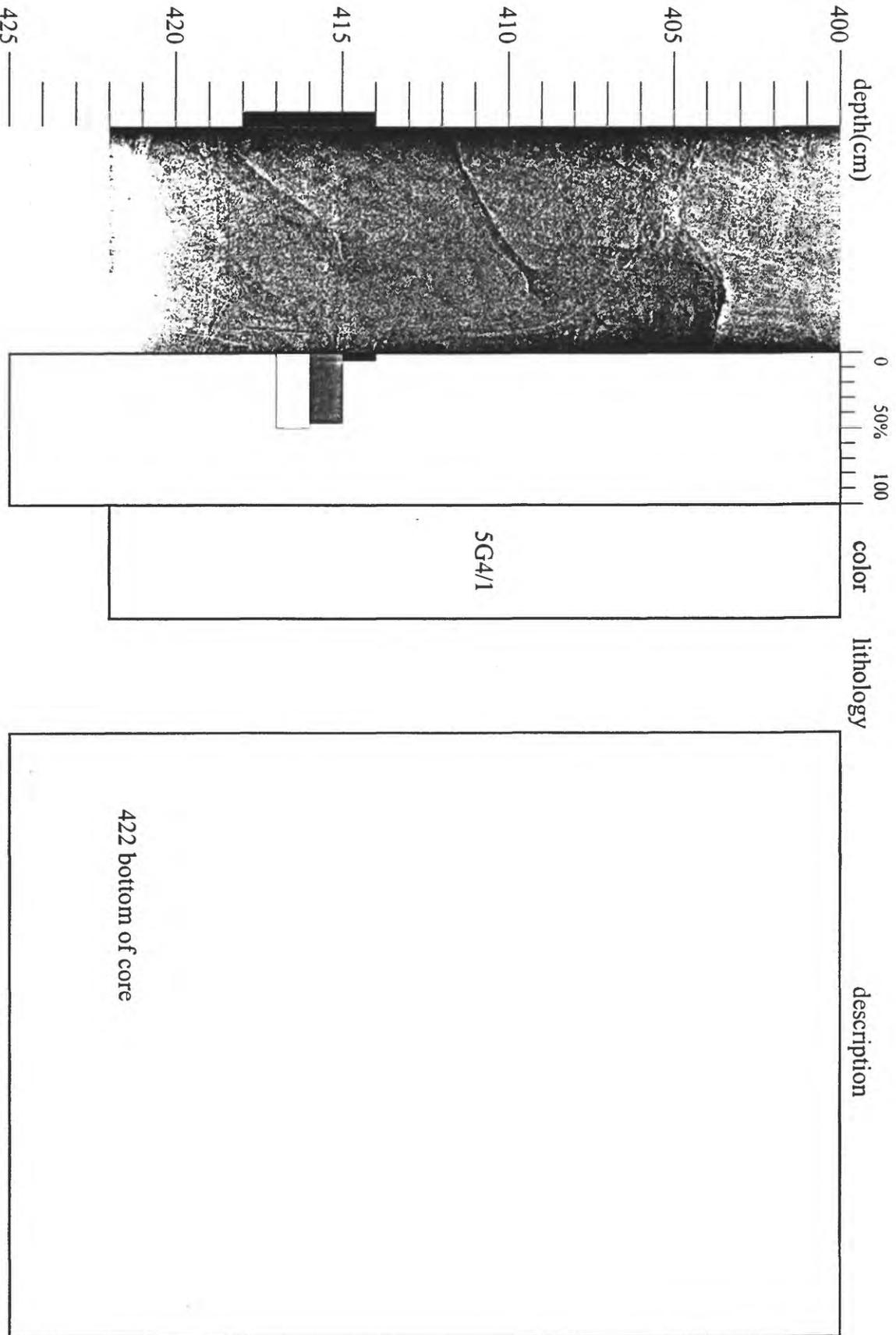
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Core PTMC 1-2



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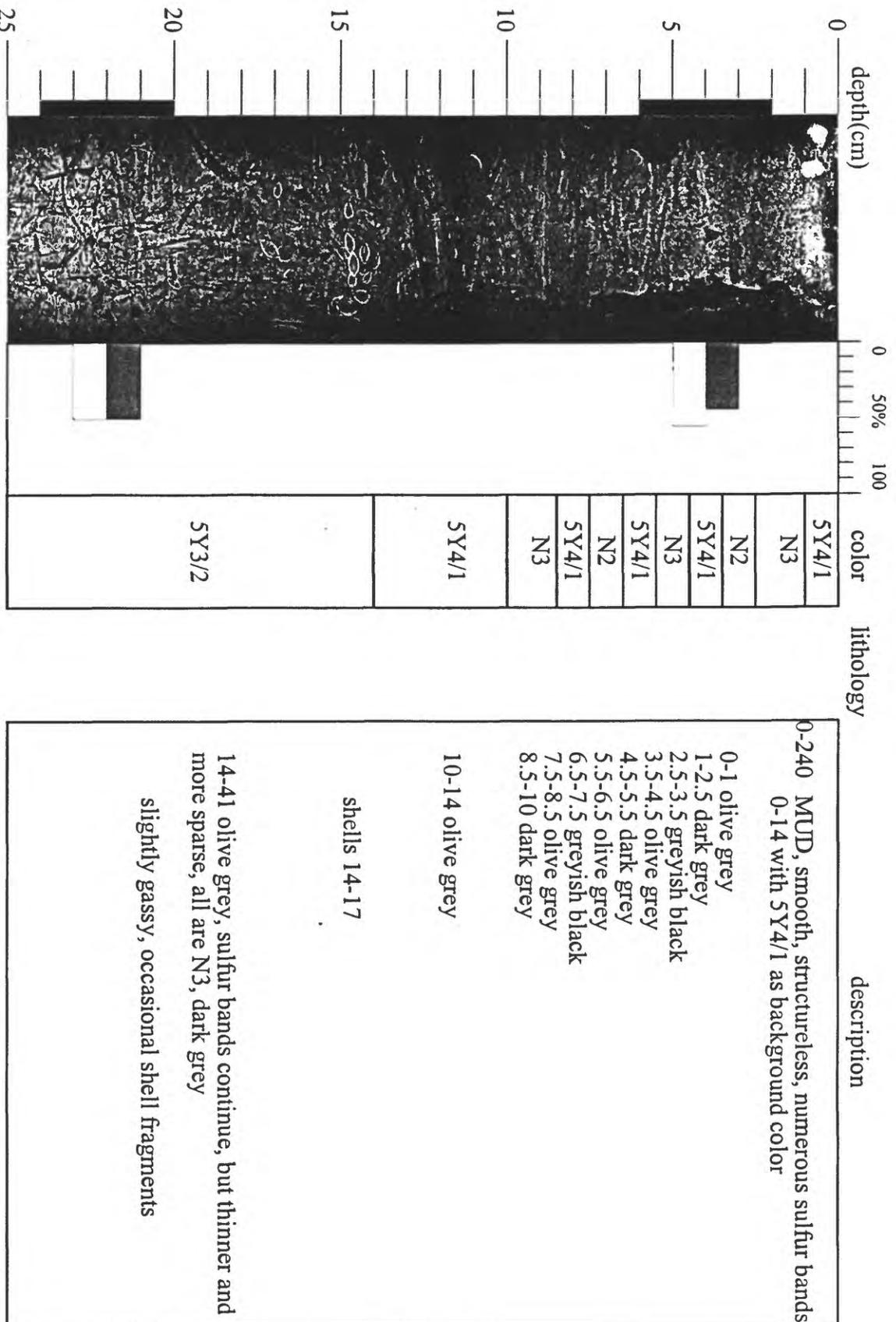
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422 bottom of core

122

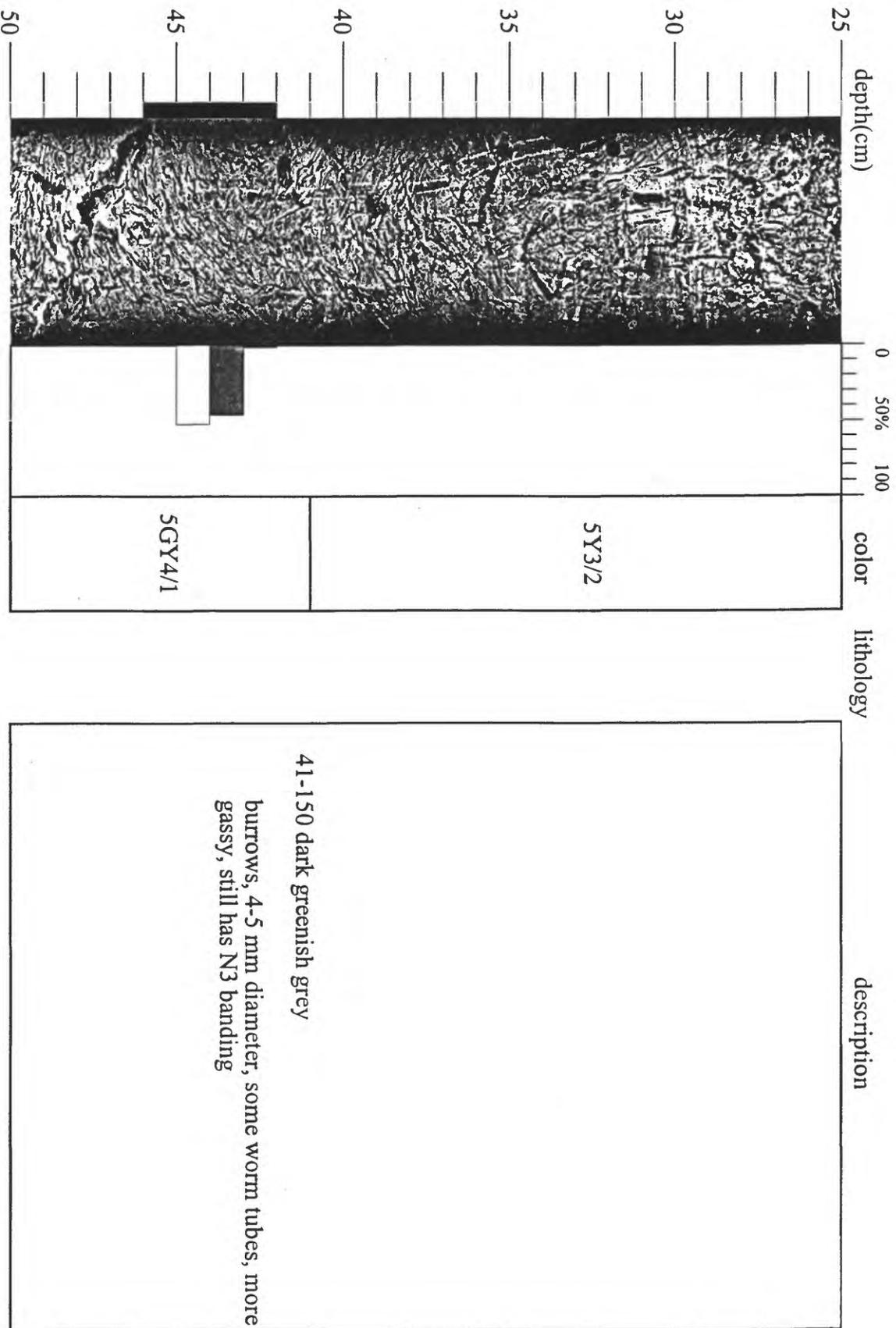
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Core PTMC 3-2



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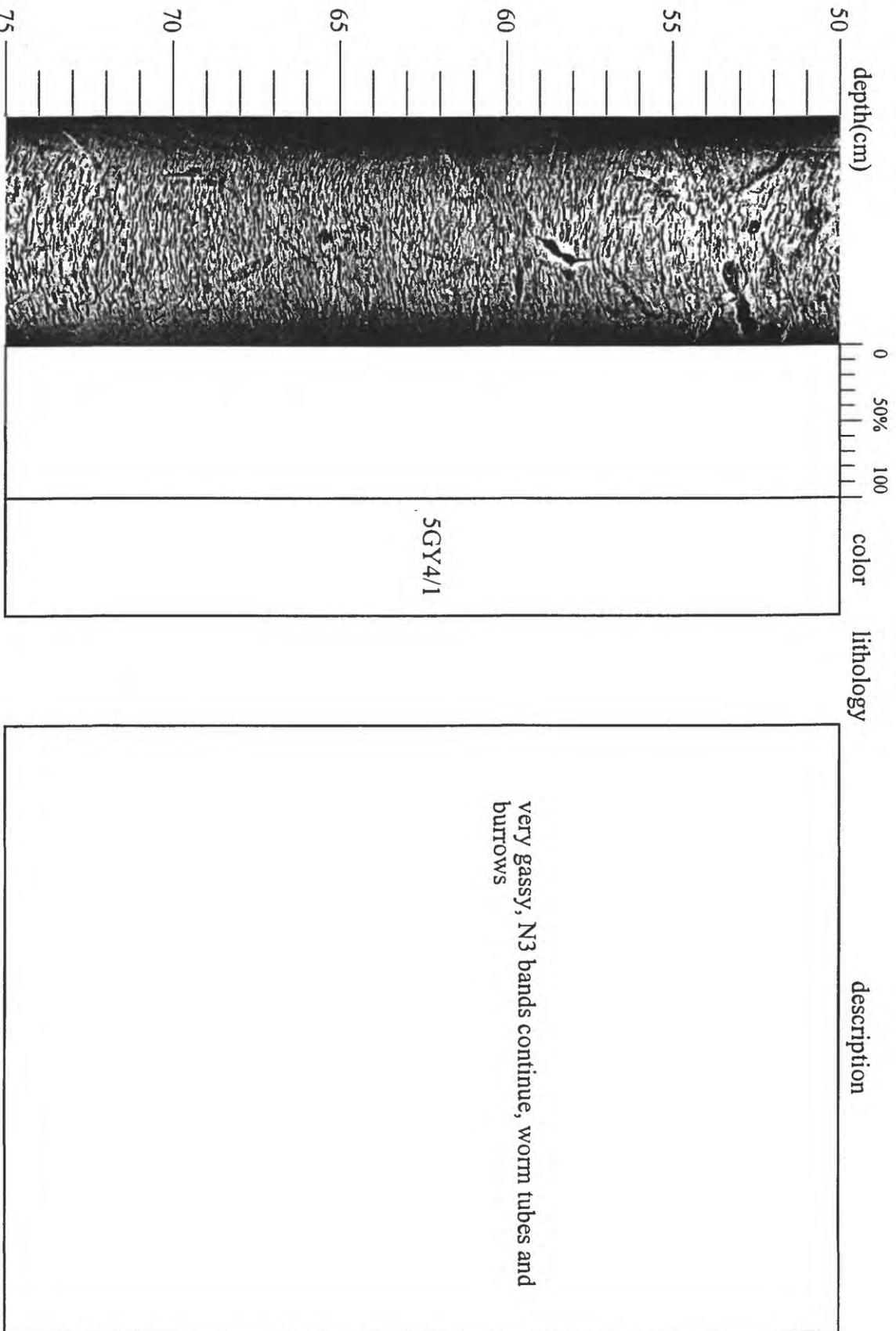
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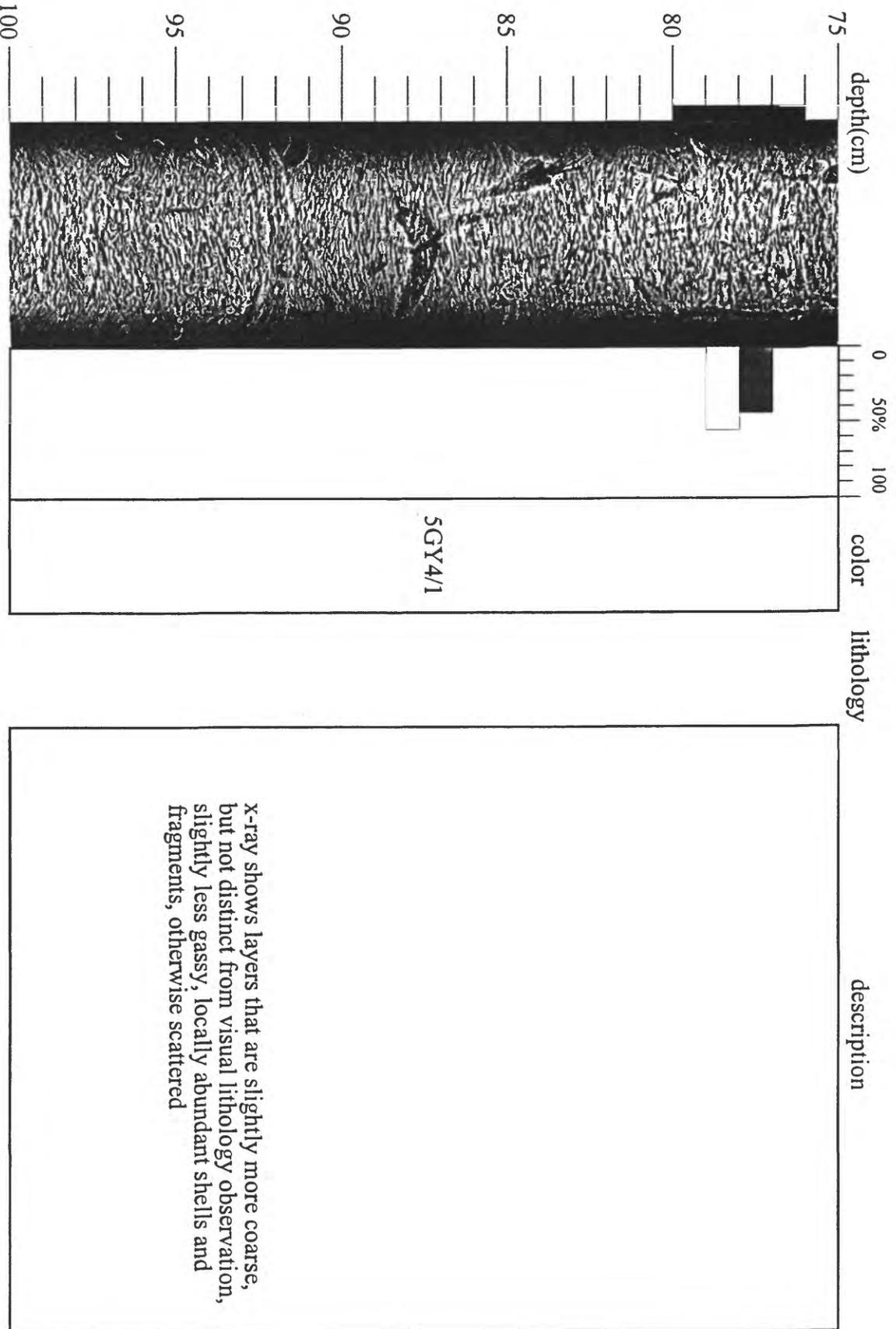
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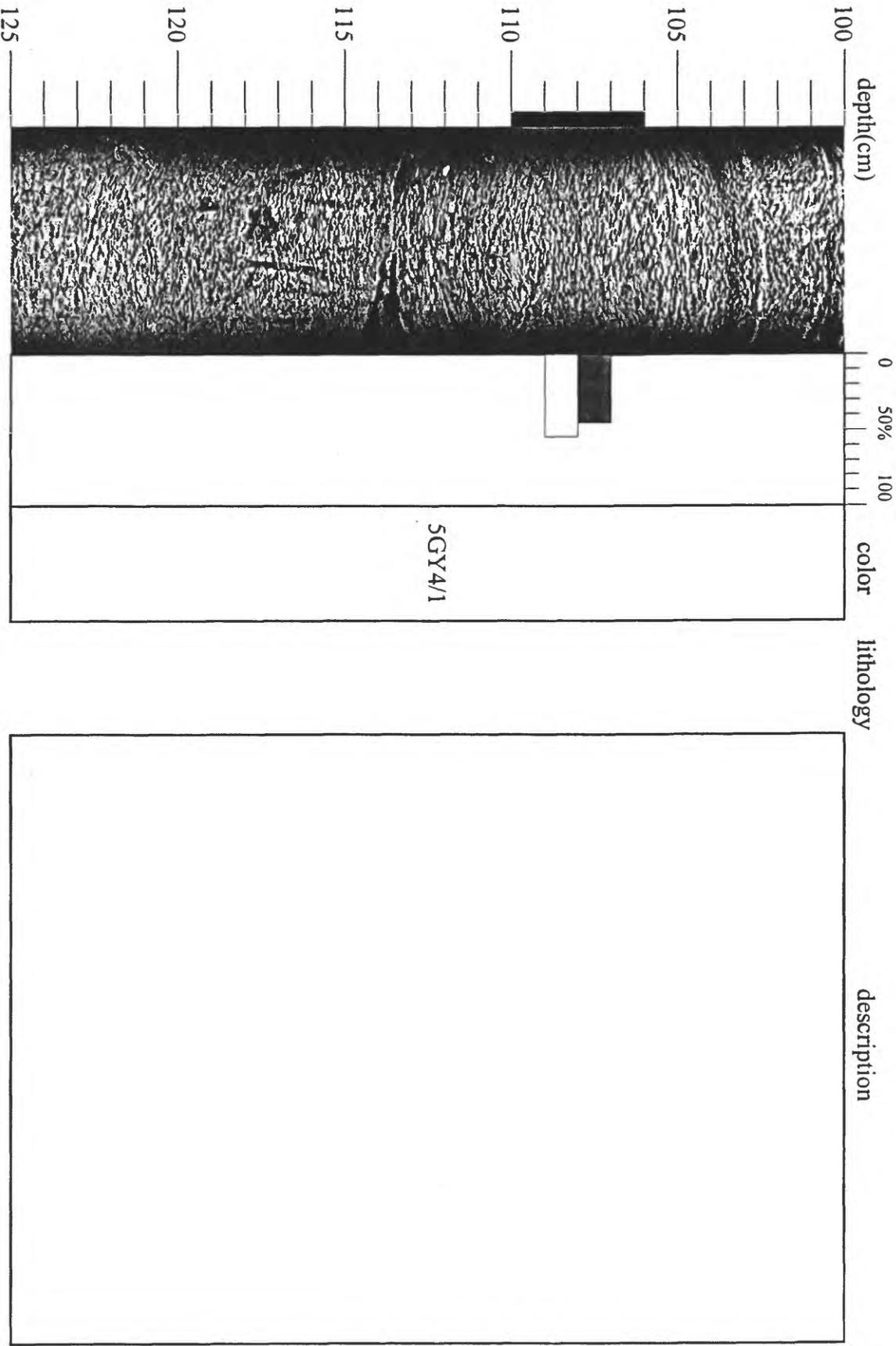


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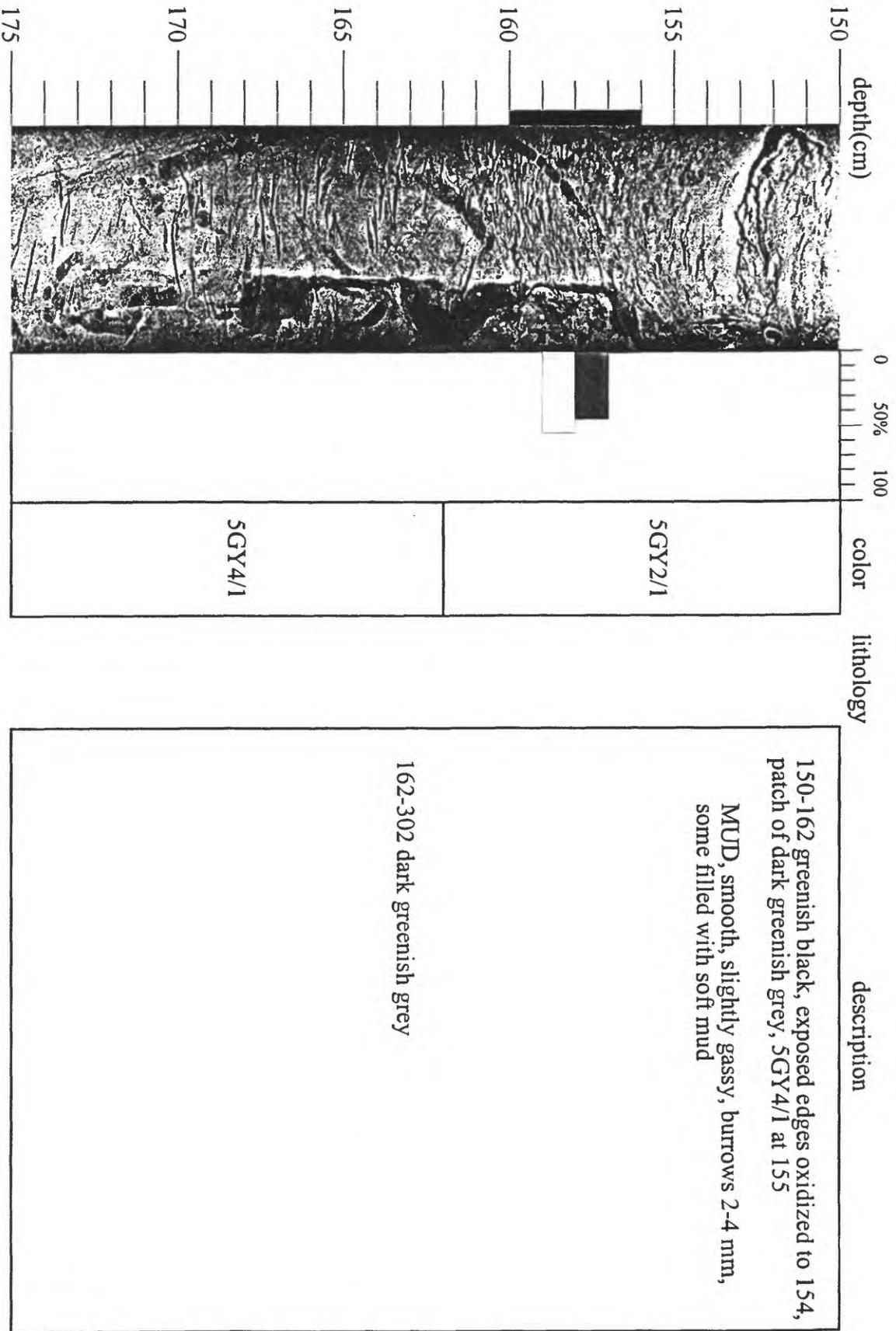


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Core PTMC 3-2



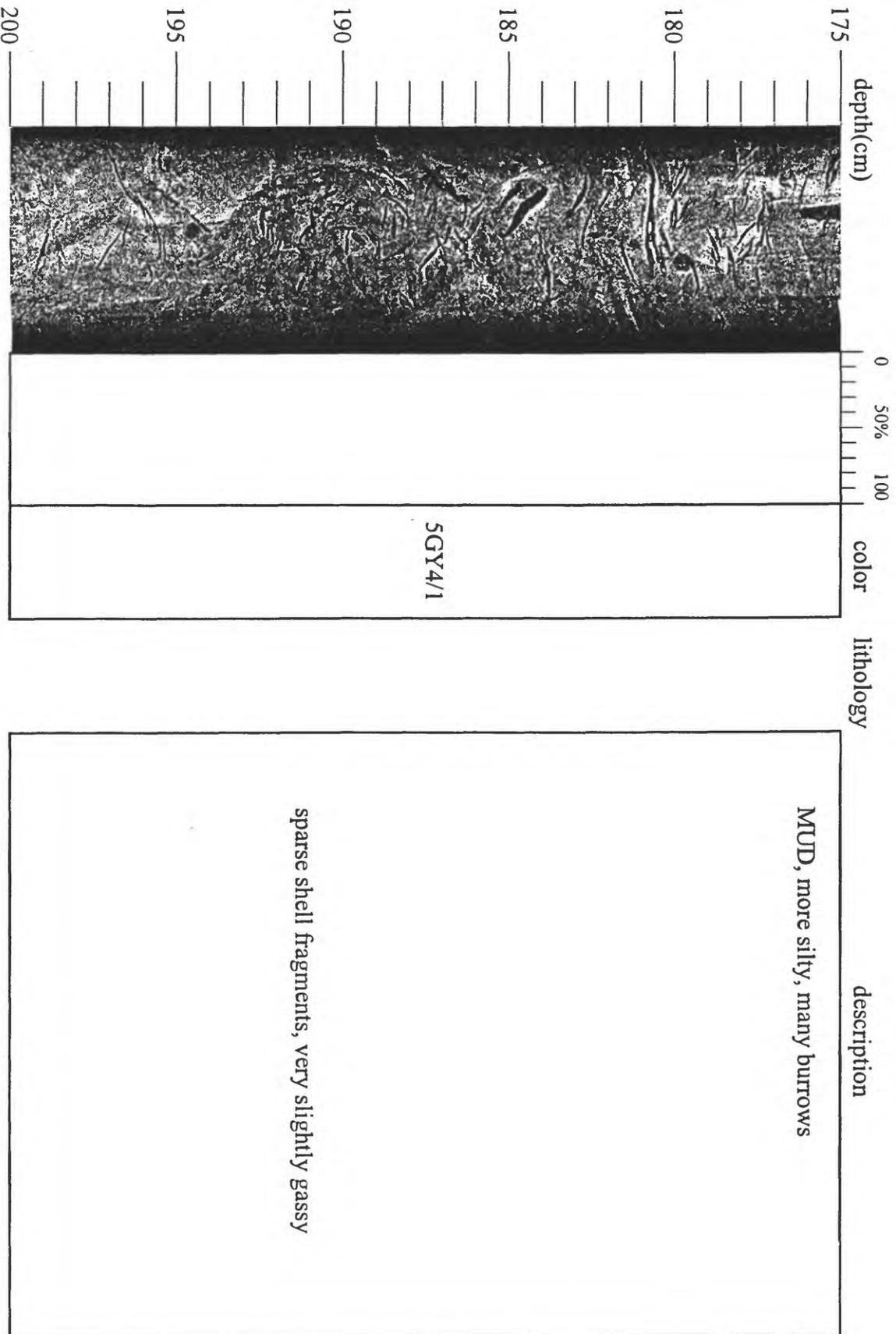
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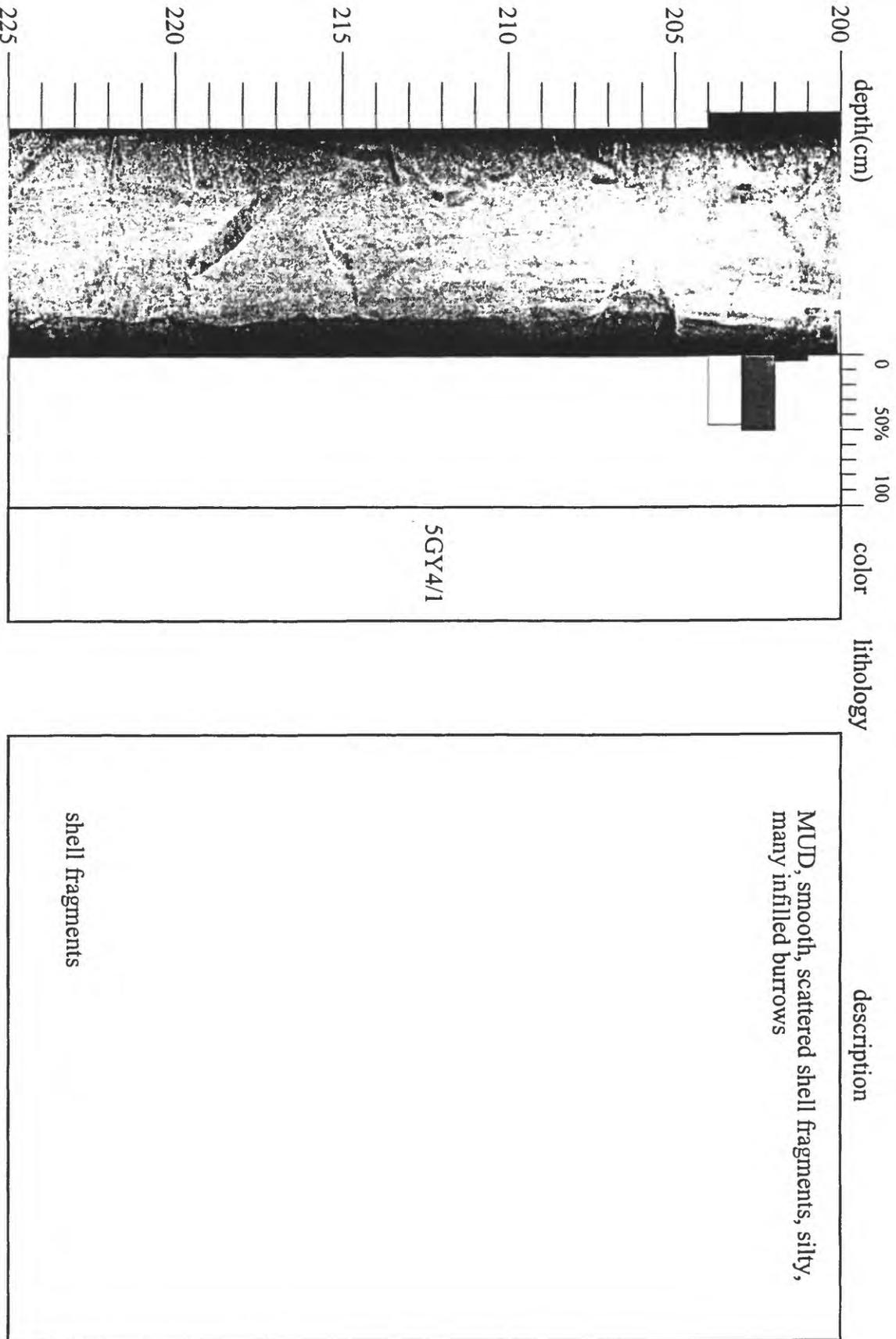
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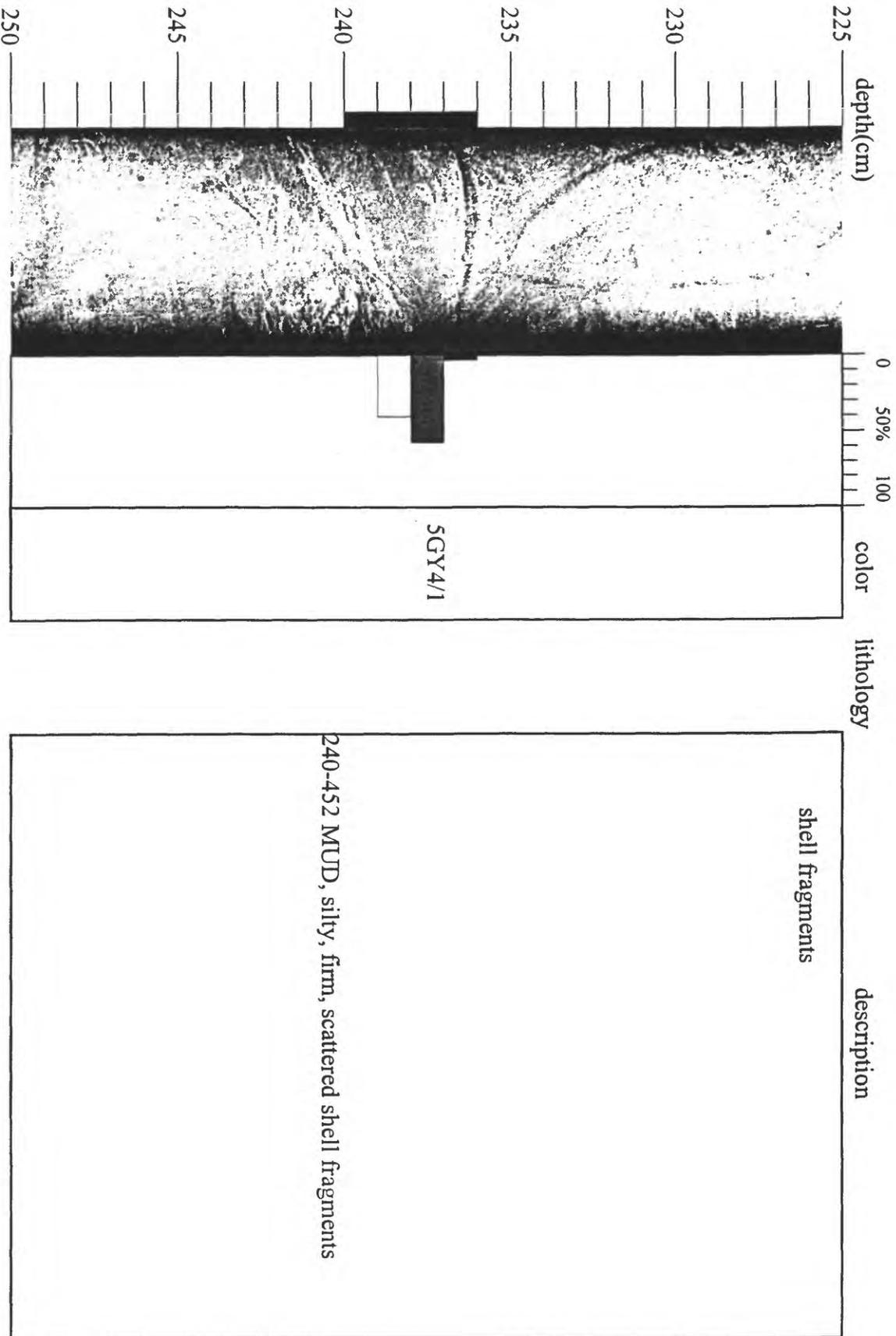
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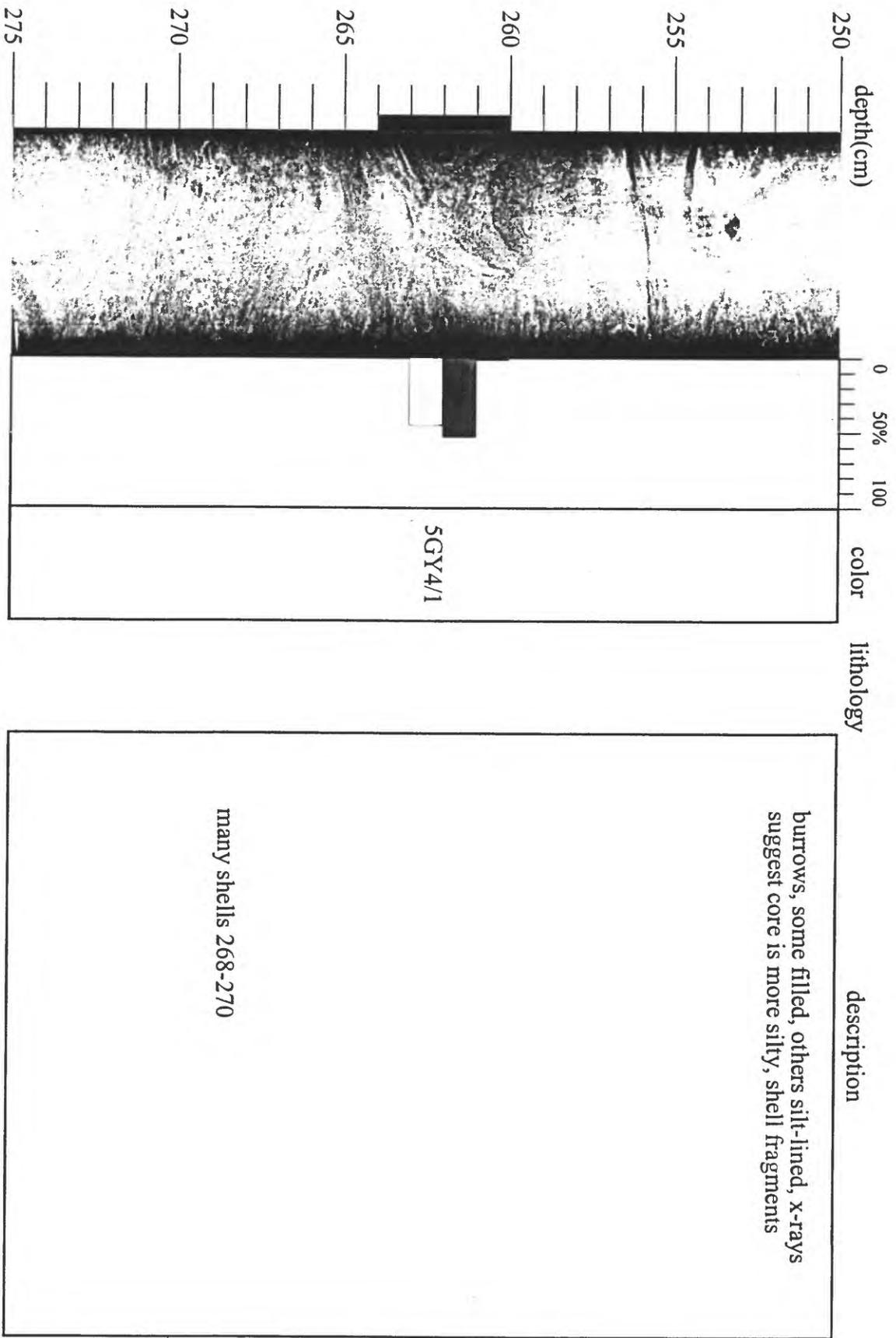
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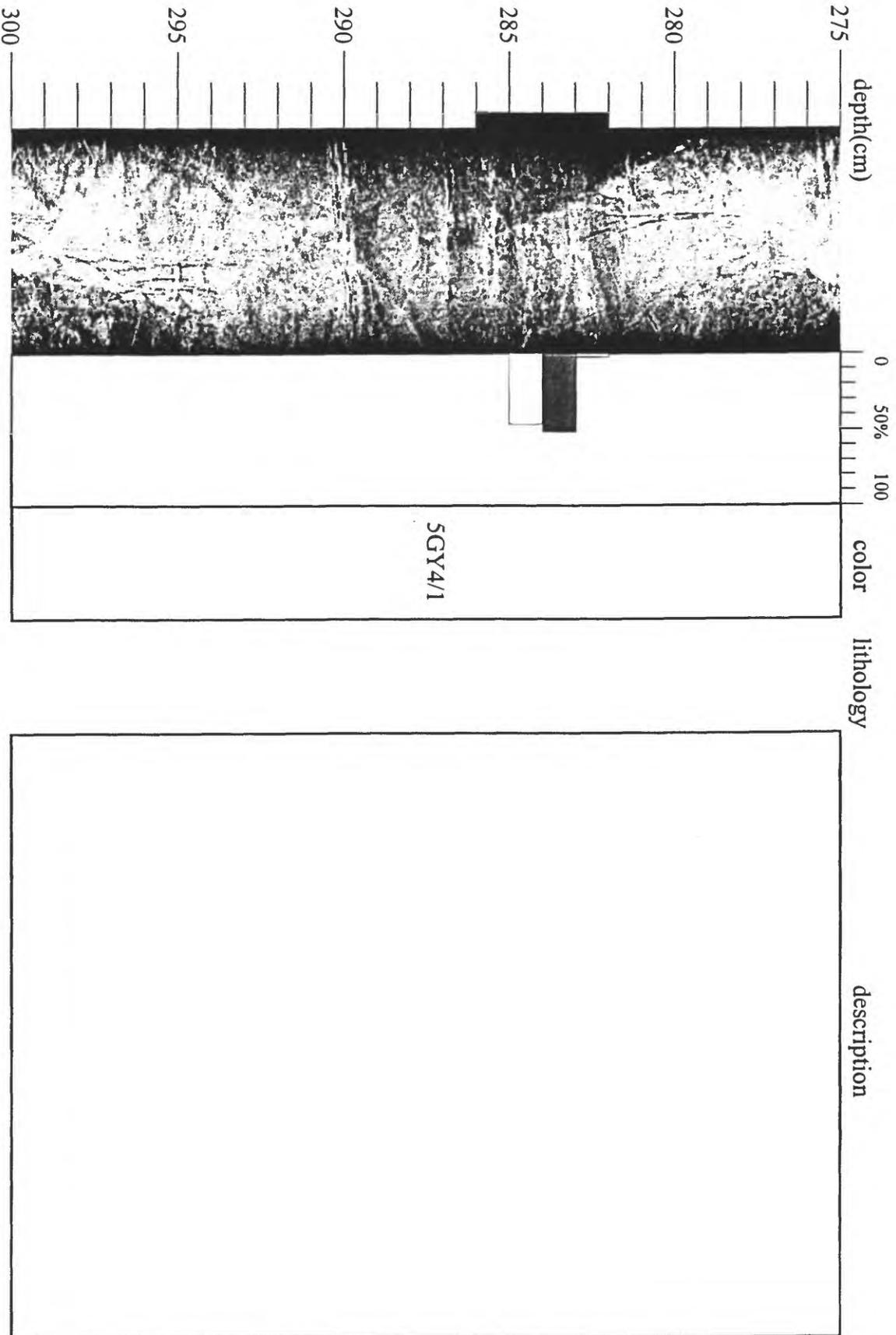
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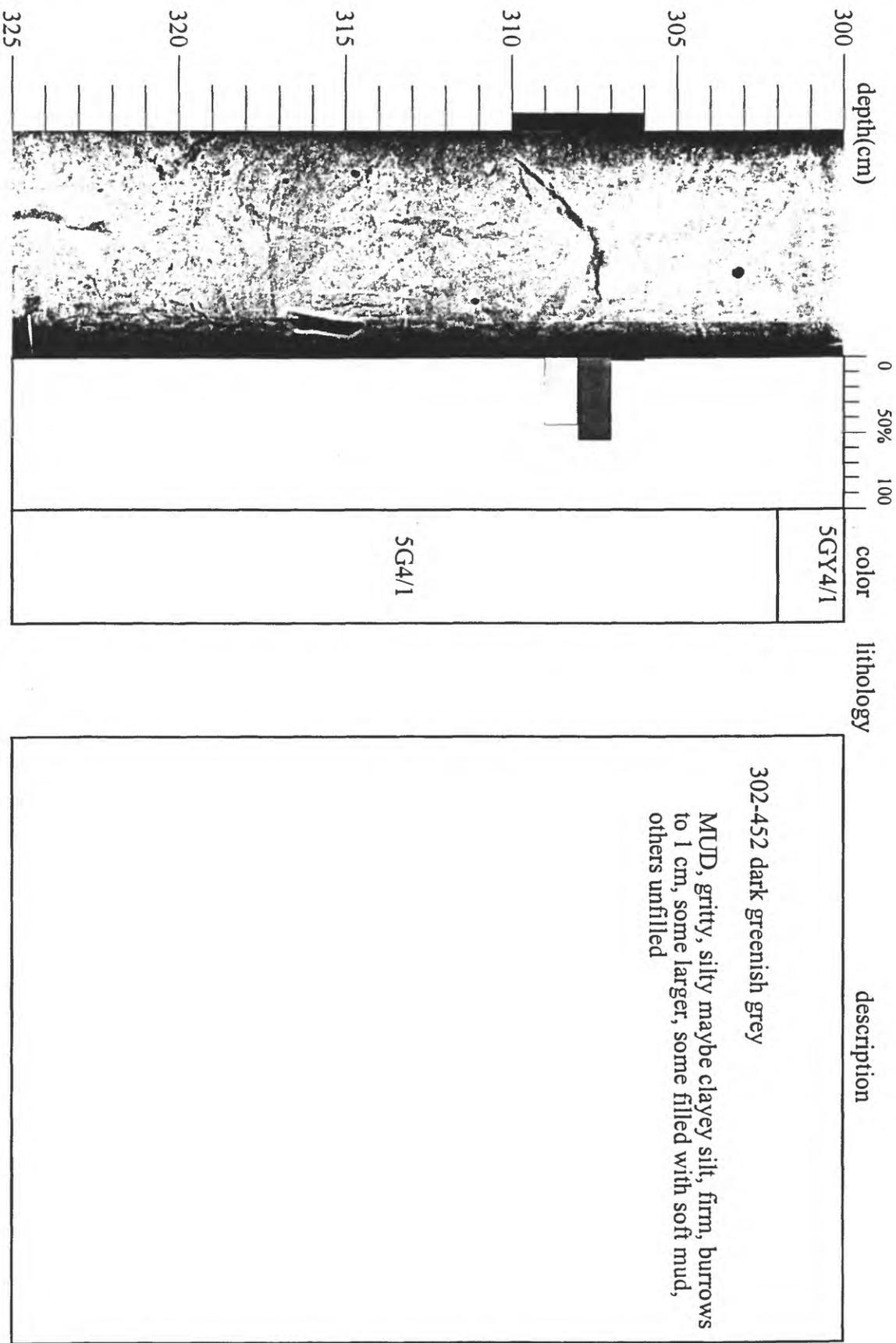
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Core PTMC 3-2



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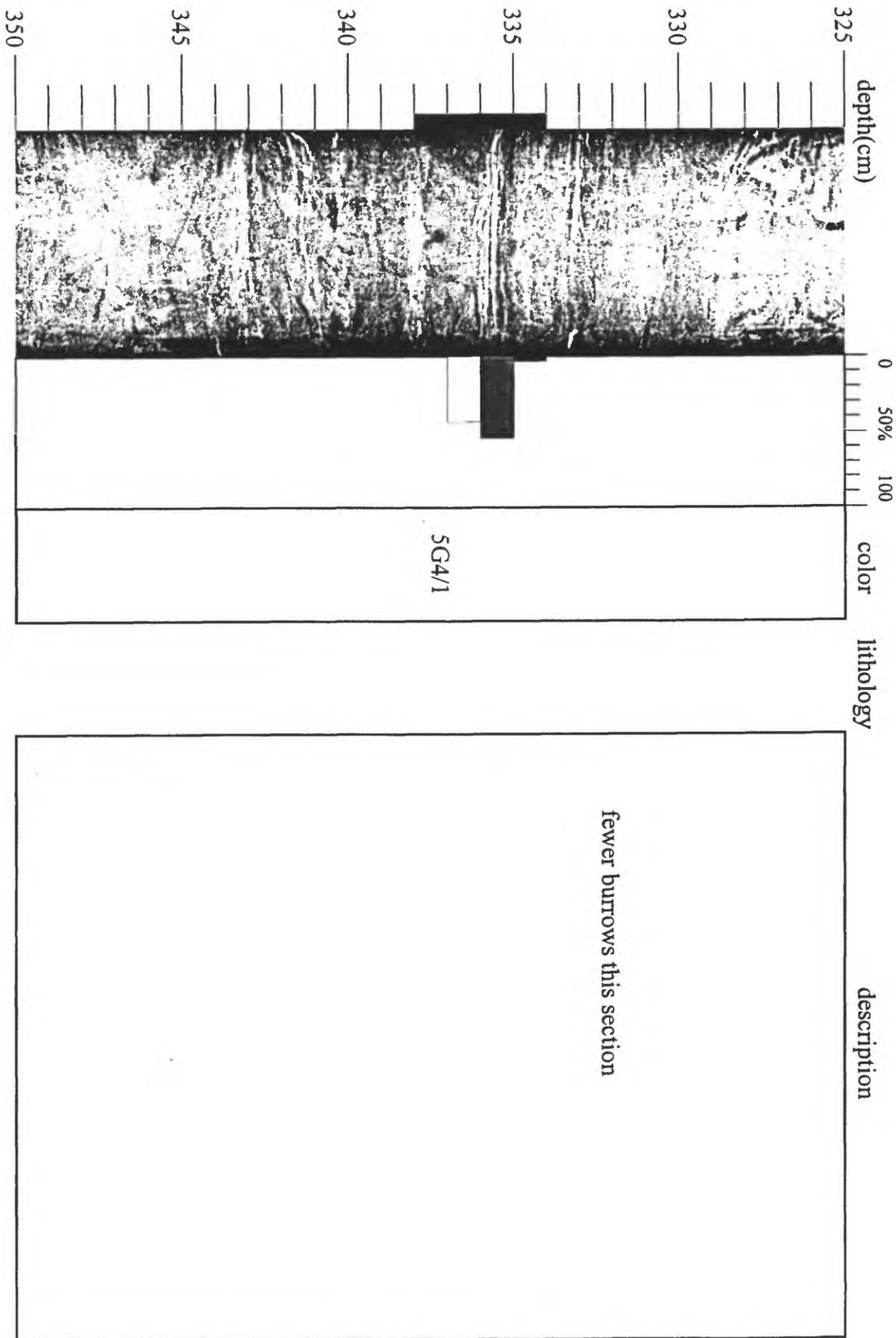
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Core PTMC 3-2



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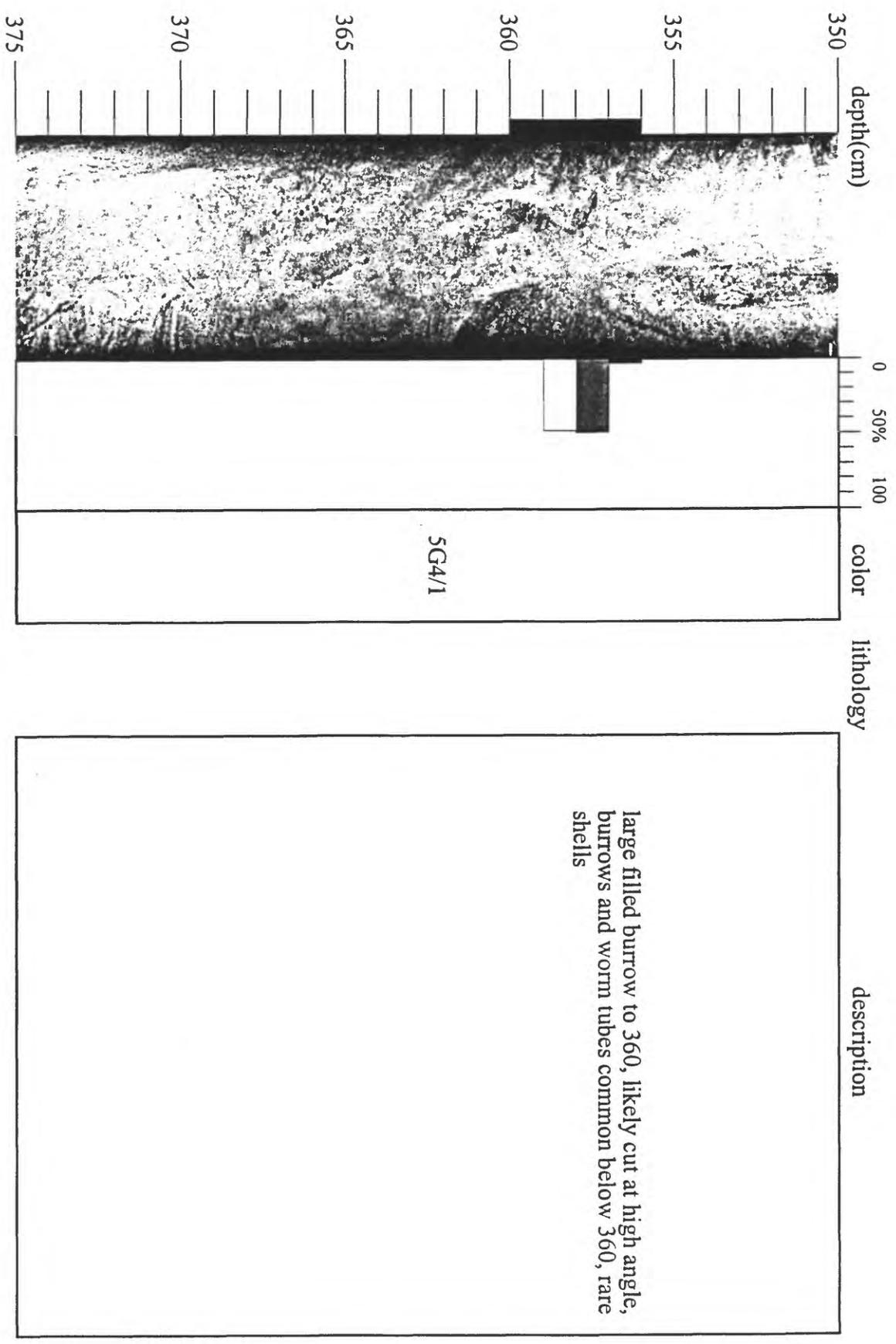


fewer burrows this section

5G4/1

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Core PTMC 3-2

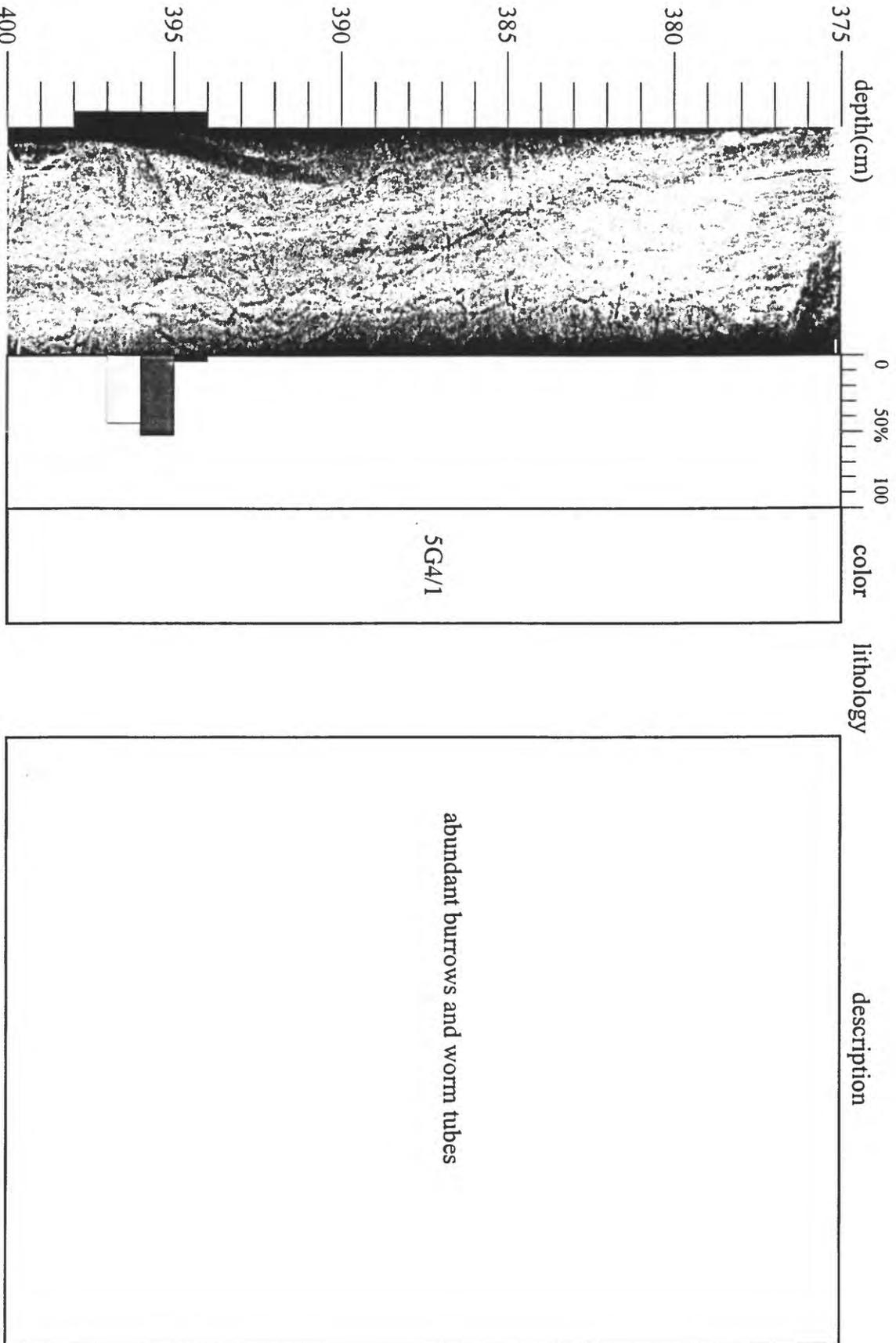


5G4/1

large filled burrow to 360, likely cut at high angle,
 burrows and worm tubes common below 360, rare
 shells

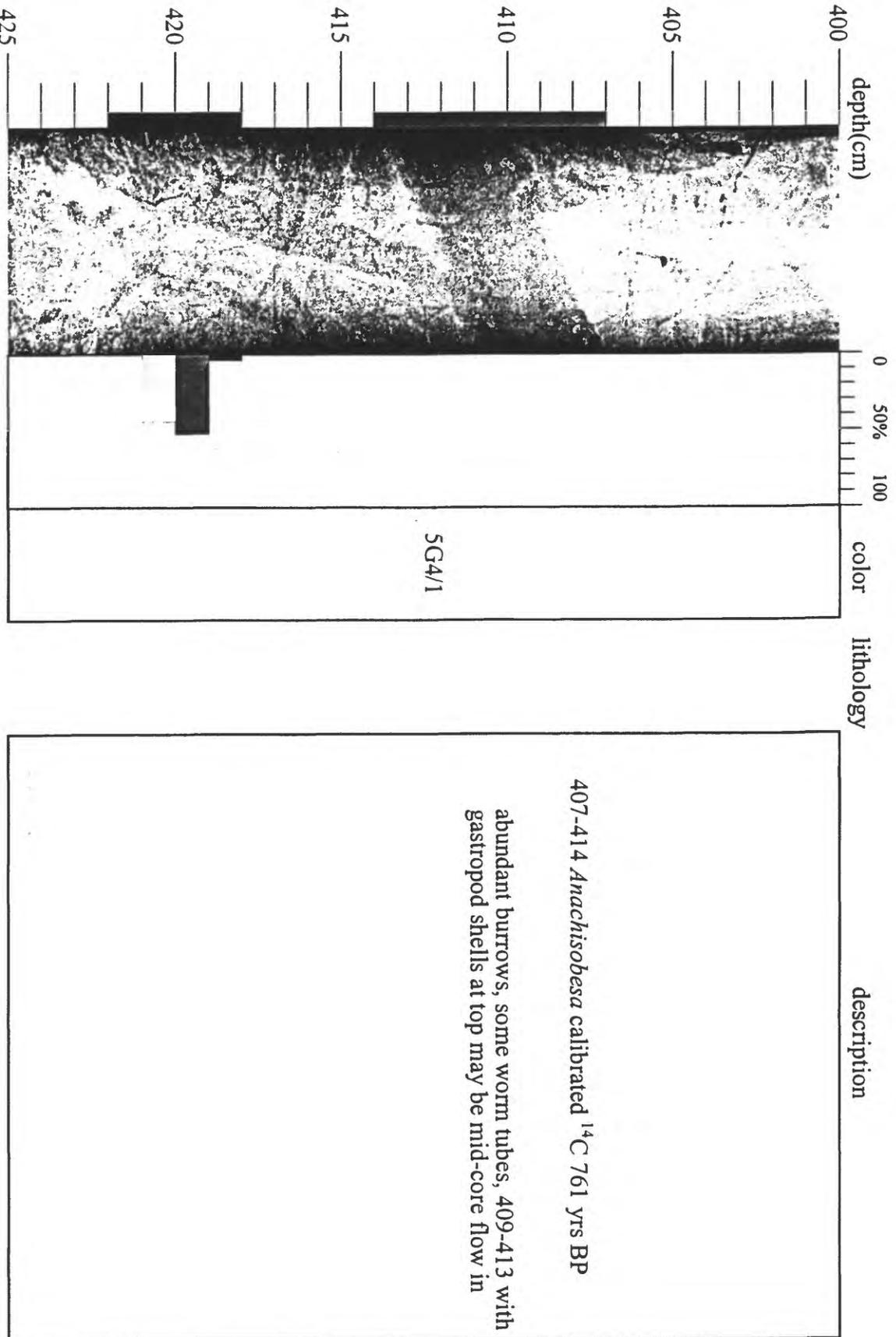
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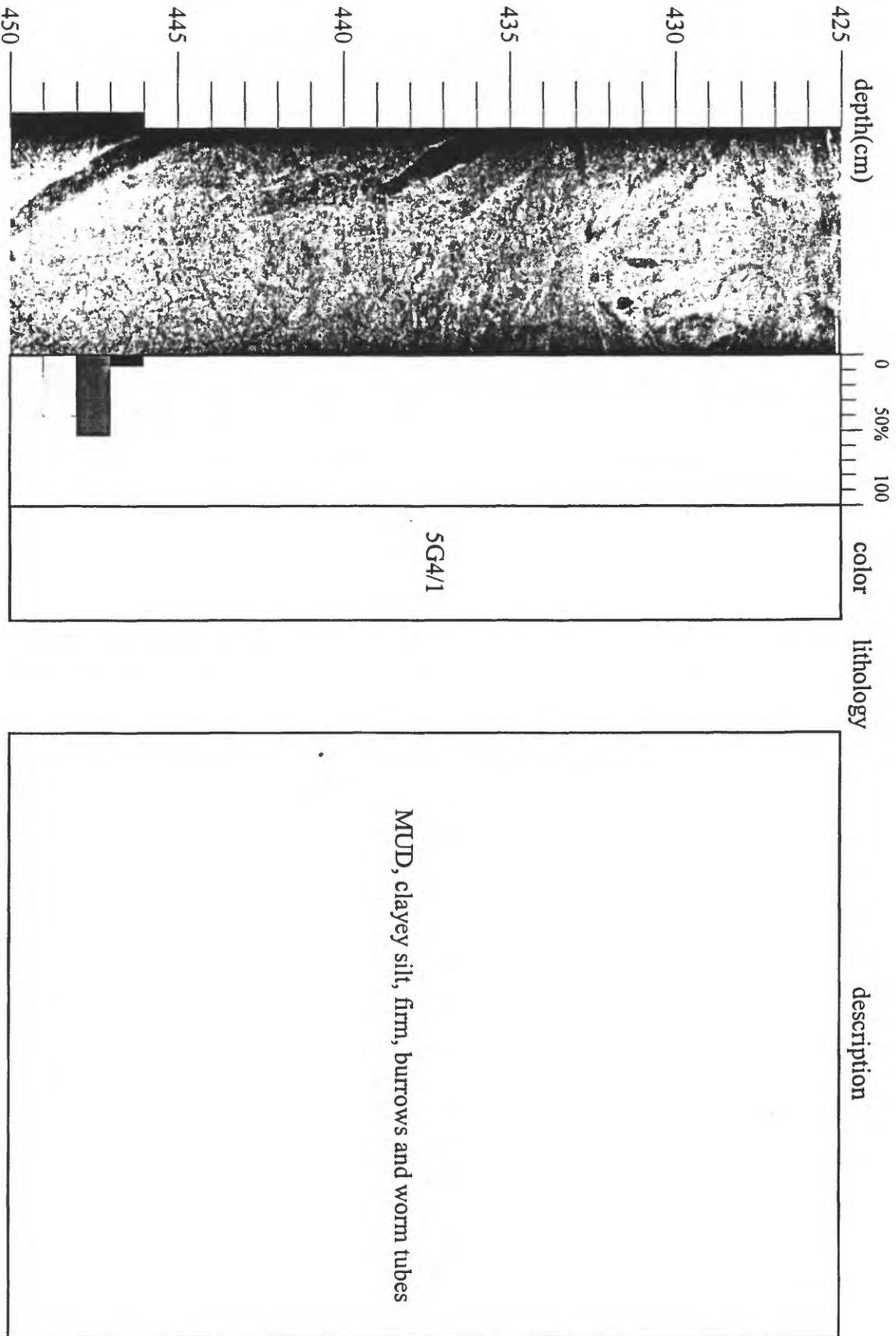


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Core PTMC 3-2



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Core PTMC 3-2

